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AGRICULTURAL ENGINEERING

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Results of a Research Survey of the Requirements of the General-Purpose Farm Tractor - - - - - - - - *D. C. Heitshu*

Discussion by H. B. Josephson, H. E. McCray, G. W. Iverson, R. I. Shawl, J. B. Davidson, R. H. Driftmier, D. B. Lucas

A Study of the Stationary Spraying System - - *F. D. Cornell, Jr., and H. L. Crane*

A Method of Calculating the Number and Size of Tractors Required for Given Conditions - - - - - - - - - *L. N. Aginsky*

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WILLIAM BOSS, President — RAYMOND OLNEY, Secretary-Treasurer

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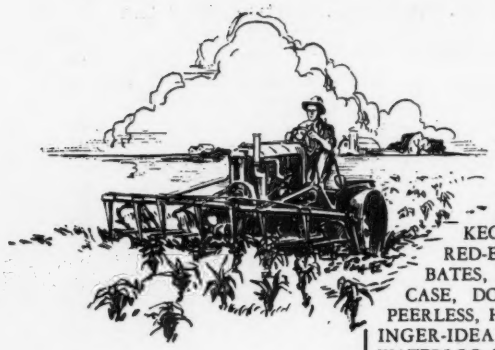

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AGRICULTURAL ENGINEERING

Vol. 10 MAY, 1929 No. 5

The Requirements of the General-Purpose Farm Tractor[1]

By D. C. Heitshu[2]

SINCE the inception of the farm tractor, the aim of tractor engineers has been to design and produce a successful general-purpose tractor. Success has crowned these efforts in practically every farm operation except row crop cultivation. The development of the successful row crop cultivating tractor is one of the most important present day problems within the scope of agricultural engineering. Obviously the solution of this problem will mark the beginning of a new epoch in power farming. It is not the object of this paper to offer a solution for the cultivating tractor problem, but rather to analyze the problem, which analysis, it is hoped, may assist in future work along this line.

A farm machinery survey, conducted in Virginia in 1925, indicated that the general-purpose tractor was the most important farm equipment problem confronting the farmers of the state. This led to an experiment station project, the object of which is to determine the basic requirements of the successful general-purpose farm tractor. However, this problem is not distinctly Virginian; neither is it southern, nor eastern; it is one involving the entire country.

During the past year a questionnaire survey of the agricultural engineering departments of the various state agricultural colleges was used to correlate the experimental work conducted in Virginia with national conditions. In this survey replies were received from thirty-eight states, thirty-six of which returned the questionnaire in completed form (Fig. 1).

The best measure of the worth of the general-purpose tractor is contained in the answers to the question: "What percentage of the farmers in your state could use a row crop cultivating tractor to economic advantage?" The average for thirty states is 31.9 per cent, with the individual state classifications showing from 1 to 90 per cent of the farms in each state as prospective general-purpose tractor farms (Fig. 2). Furthermore, it seems certain that inter-row tillage cannot be done away with entirely, since inter-row tillage is recommended, in the thirty-four states answering this question, on the following basis: One cultivation, nine; two cultivations, twelve; and three cultivations, nine. Only two of the states deemed it advisable to control weeds and conserve moisture by thorough tillage previous to planting, limiting the later tillage operations to the use of the drag harrow, weeder, and rotary hoe. Two states did not make definite recommendations.

A major factor in the cultivating tractor problem is the varying widths of row spacings used in different parts of the country. The distance between rows varies from 12 to 72 inches; and crop, soil, climatic, and economic conditions allow but little argument in favor of changing the established widths. It is the duty of the engineer to meet these conditions with manipulations that will not adversely affect the quantity or quality of the yield of the crop concerned. For example, an alternate spacing of 9-15-9-15 inches in all probability is as practical as a 12-12-12-12-inch spacing, and may make tractor cultivation possible. Within certain limits row widths can be standardized. In a given agricultural province there is no logical reason for a few farmers planting beets or beans in 18 or 21-inch rows, when the large majority use 20-inch rows. Such standardization of row widths should be encouraged wherever practicable.

An analysis of the data secured in relation to the width of rows (Fig. 3), indicates that the normal width of rows falls between 36 and 48 inches. To fully adapt the tractor to inter-row tillage operations, however, it is necessary that the tractor work in rows from 30 to 48 inches in width. For rows smaller than 30 inches or larger than 48 inches, some combination of widths can be arranged to adapt the crop to tractor cultivation. Fig. 4 shows the

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December, 1928.

[2]Assistant agricultural engineer, Virginia Agricultural Experiment Station. Assoc. Mem. A.S.A.E.

Fig. 1. Sketch of area covered by replies to general-purpose tractor questionnaire

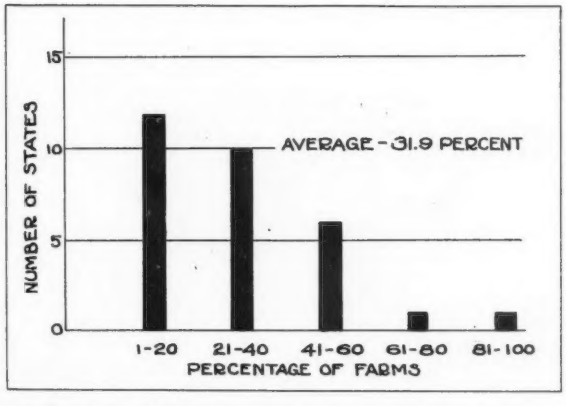


Fig. 2. Graph showing the number of farms adapted to the use of the general-purpose tractor

range of row widths commonly used in each of the reporting states: Eleven states have all crop rows 36 inches or greater in width; eleven states have some row crops in rows less than 36 inches wide, with the majority of crops in rows over 36 inches wide; and fourteen states have important crops growing in rows less than 36 inches wide. Considering the crops involved, their importance and the areas concerned, the ideal general-purpose tractor must be able to cultivate rows varying in width from 30 to 48 inches.

The height and width of plants at the time of the last cultivation varies even more than does the width of row. The maximum height of the cultivated plants in the different states ranges from 24 to 72 inches, the 36 to 41-inch classification covering the major group (Fig. 5). The average height at the time of the last cultivation is 41.1 inches, with corn representing the major crop in this class. The maximum width is even less fixed, extending from 6 to 60 inches. The average maximum width of plants is 28.6 inches. In twelve states potatoes have the maximum spread; in 8 states, corn; and in 8 other states, cotton.

In the poll as to whether it is desirable to have the clearance of a cultivator sufficiently large to care for the maximum height and width of plants, thirty-one states voted "yes" and four "no." That the majority of crops can be cultivated with less clearance than the actual size of a plant demands is shown in the average desirable clearance, which is 32.6 inches vertically, and 23.1 inches horizontally. The clearance necessary in row crop cultivation can be chosen only by arbitration. All the data available show that 30 inches vertical clearance, and 24 inches, or even less, horizontal clearance should be sufficient for practically all crops. Properly designed shields can protect some crops requiring greater clearance than specified; but it appears that under extreme conditions, the one-horse walking cultivator or the so-called "garden" tractor must be used. In this connection it would be well worth knowing whether or not the last cultivation of row crops is an asset or a liability. Some states are recommending that the number of inter-row tillings be reduced. In cultivation, as with other operations, it is often well for the engineer to carefully review the specifications for a given operation, even though those specifications are the product of a competent agriculturist.

In an endeavor to determine the more desirable features of the cultivating tractor opinions were obtained as to the type, size and range of operating speeds. The three-wheel, two or four-row type of tractor claims fifteen favorable states; the four-wheel, three-row type five states; and the two-wheel high-clearance tractor with unit hitch is favored by one state. "No preference," "undecided," or "no answer," was the reply from fourteen states. One

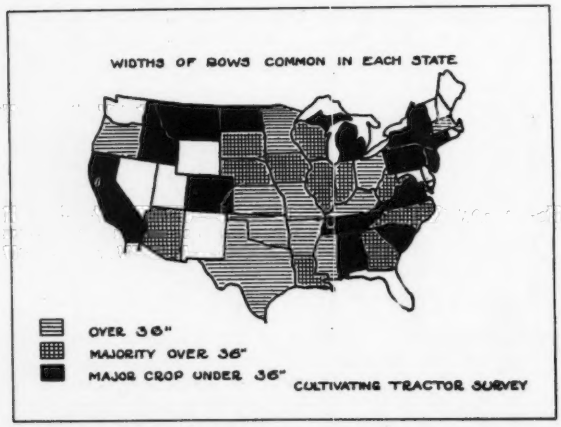


Fig. 4. Sketch showing characteristic row widths of each state

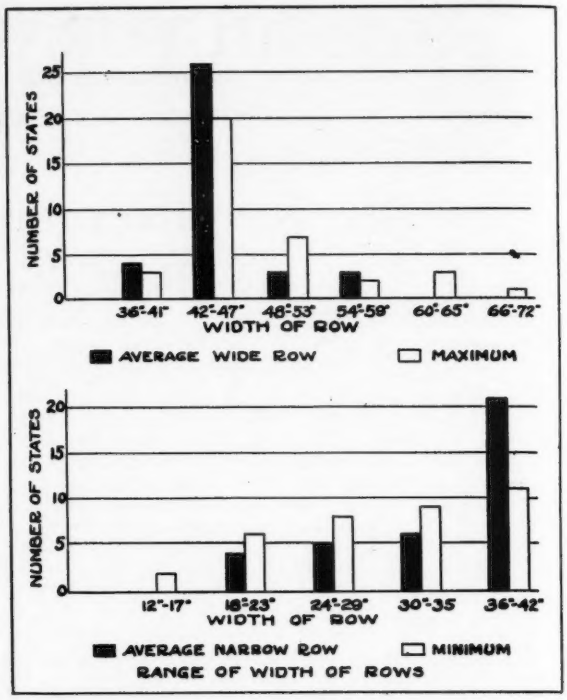


Fig. 3. The range of row widths of cultivated crops in various states

mechanical feature upon which a large majority agree is the question of mechanical changes to adapt the tractor to cultivation. The poll is twenty-seven against to four for the shifting of parts to increase clearance or otherwise obtain desirable or necessary features when cultivating. A tractor should cultivate as well as plow, without necessitating a shift in parts.

A marked consistency is shown in the power rating believed desirable for this type of tractor. A 10-20-hp. rating is most popular (Fig. 6). The average of all answers gives the ideal general-purpose tractor a rating of 10.1 hp. at the drawbar, and 19.6 hp. on the belt. A minimum of 20 b. hp. seems desirable, hence the drawbar rating should not be less than 12 hp., as any modern tractor should develop at the drawbar at least 60 per cent of its rated brake horsepower.

The weight of the general-purpose tractor should be kept as low as consistent with good construction and effi-

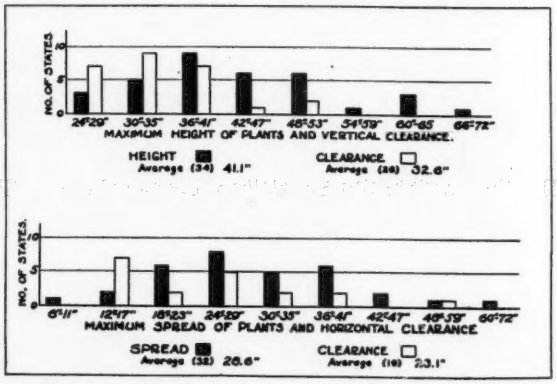


Fig. 5. Graph showing the range of maximum row heights and desired vertical clearances

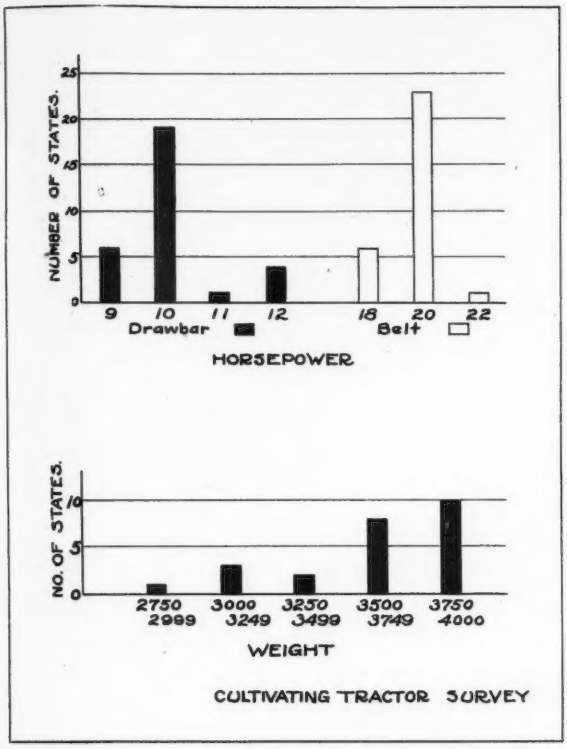


Fig. 6. Diagram of summarized weight and power demands

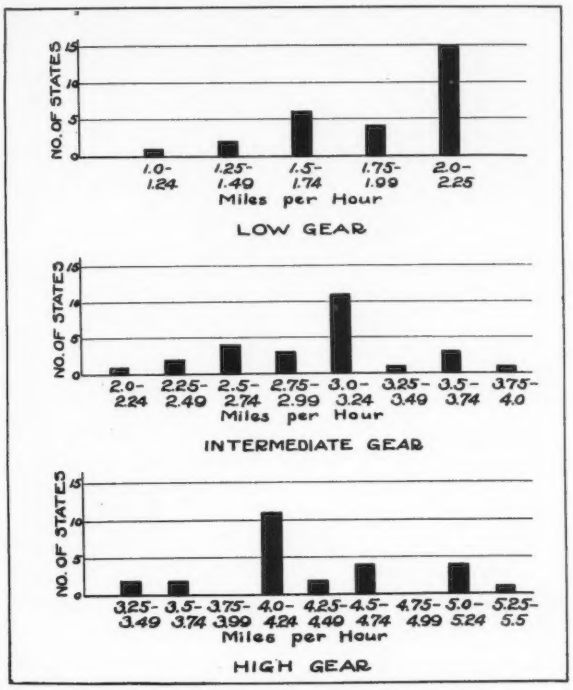


Fig. 7. Diagram of summarized speed demands

cient traction, as indicated by the estimates given by the different colleges. The lowest figure is 2800 pounds, none exceeds 4000 pounds, and the average is 3596 pounds. The largest range group is the one between 3750 and 4000 pounds (Fig. 6). Dimensions varied to a large degree, but the averages were 60.0 inches high, 76.7 inches wide, and 112.1 inches long. The general opinion is that the dimensions of the tractor are not as important as the weight, but both the weight and the turning radius must be kept as low as is consistent with good design.

Three forward speeds are an essential feature of the general-purpose tractor, the results of the survey indicate. Only two states believe two forward speeds to be sufficient; twenty-five favor three speeds; and three want four speeds. The average for the first speed is 1.8 miles per hour, the suggested speeds for this gear varying from 1.0 to 2.25 miles per hour (Fig. 7). The ideal second speed is 2.9 miles per hour, with suggestions varying from 2.0 to 4.0 miles per hour. In third speed the ideal is 4.2 miles per hour. The minimum speed desired in "third" is 3.25 miles per hour, while the maximum is 5.5 miles per hour. Those desiring a fourth speed wish it for the road, and suggest a speed between 5 and 6 miles per hour.

EXPERIMENTAL WORK IN VIRGINIA

The general requirements for the general-purpose tractor and for its most important accessory, the cultivator unit, having been established, the detailed specifications for this equipment next needed analysis. The Agricultural Engineering Department of the Virginia Agricultural Experiment Station has dealt specifically with this problem since 1926, and herewith is presented a full progress report of this work. The data presented and the conclusions drawn from the data are not conclusive, but are offered to assist in the final solution of this complex problem.

The Cultivator. The field work in Virginia indicates that the most important feature of the cultivator attachment is that it be constructed as a separate unit from the tractor. This requires that it be practically self-supporting and not rigidly attached to the tractor. The assumption that the logical position of the cultivator is ahead of the tractor, where its operation can be observed in conjunction with steering, gives the separate unit cultivator four advantages: Flexibility, little or no weight thrown on the tractor to affect steering, ease of attaching and no interference between the gangs and the tractor in any adjustment or position.

Flexibility in a tractor cultivator is as essential as three-point suspension is to the tractor. A forward mounted cultivator unit cannot operate successfully, except in a field which is perfectly level, unless it can conform to the topography of the field being worked. This is impossible with rigid mounting, as the lateral plane of the cultivator and tractor is established by the rear wheels and axle. Since the distance between the rear axle and the cultivator gangs will vary between 6 and 10 feet, the change of the lateral plane of the cultivator is easily observed in field operation. Fig. 8 shows a "skip" resulting from the shifting of the lateral plane, a common failure in a rolling field when a tractor cultivator with rigid coupling is used. Equally as bad is the opposite trouble of the shovels sinking to an excessive depth from the same cause. The longitudinal plane of the cultivator is not as important as the lateral, but under certain conditions its shifting causes trouble. Flexibility in both planes can be secured easily, and is essential if the general-purpose tractor is to work in rolling, hilly, terraced, irrigated, or washed fields.

A flexibly mounted cultivator unit prevents excessive weight being thrown upon the front end of the tractor. This is an important asset in sidehill cultivation. When working on a side slope the tractor tends to creep, and added weight on the forward portion of the tractor increases this creep. For this reason designers should endeavor to make the cultivator unit as self-stabilizing as possible. The result of sidehill creep is also shown in Fig. 8. Here the row of corn is completely covered by the skidding of the front wheel while endeavoring to hold the

rigidly mounted cultivator in its proper position with respect to the row. This skidding, with its resulting damage to the young crop, is not entirely the product of the rigid mounting of the cultivator, but certainly the weight of the cultivator aids in causing it. Other factors tending to produce their side slip will be discussed more fully later on in this paper.

The cultivator for the general-purpose tractor must be arranged so as to allow it to be readily attached or detached, as the tractor is needed for work other than cultivating during the cultivating season. A separate unit cultivator is an asset in making these necessary changes as no heavy lifting or moving is required. The cultivator should be made so that the tractor can be driven into it and coupled in five minutes; this operation should not require more labor than the farmer and his helper can furnish.

The fourth advantage of the separate cultivator unit favors the designer. When the cultivator is rigidly mounted it must be kept compact, and as close to the tractor as possible. This complicates the design, and the interference of parts is common. The use of a unit cultivator eliminates this trouble.

A second major requirement of the tractor cultivator is the cultivation of the wheel tracks of the tractor. This is necessary for two reasons: First, the packing effect of the wheels destroys the mulch established by the cultivating process, and tends to firm the weeds in the soil so that they readily resume growth. Second, the packed strip of earth in the middle of the row forms a potential gulley which readily starts erosion with a heavy rainfall (Fig. 9).

To cultivate the wheel tracks of the tractor necessitates having front and rear cultivator gangs, the front gangs to cultivate near the crop, and the rear gangs to cultivate the middle of the rows after the passing of the tractor. Though this complicates the cultivator construction, it introduces several advantages. In addition to meeting the requirement of tilling the packed tracks of the wheels, the front and rear cultivator gang arrangement balances the weight thrown on the tractor and thereby increases steering stability; furthermore, the tractor wheels have firm soil upon which to operate, thus increasing the stability of the tractor, and reducing the ridging effect of the wheels, as illustrated in Figs. 8 and 10. The rear gangs can be mounted rigidly upon the tractor as they are near the controlling axis; i.e., the rear axle.

Self-leveling, or floating, cultivator gangs promise to be successful provided a simple floating hitch can be developed. If this type of gang can be fully perfected, a rigidly hitched cultivator may prove successful. But because of the seemingly complicated mechanism necessary to secure floating gangs the separate unit cultivator is preferred. However, simple floating gangs with a limited range of movement would add to the performance of the separate unit cultivator.

Whether to make the gangs so they can or cannot be shifted is an important question confronting every tractor cultivator designer. The gang shift has its advantages and disadvantages. In the field tests conducted at the Virginia station, a plat, designated by the letter "A," was cultivated with the gang shift in use. Plat A, containing 1502 corn plants drilled in four rows 500 feet long, suffered the following losses: Plants covered, sixteen; plants broken off, four; plants plowed out, four; total damage, 1.7 per cent. In Plat B the gangs were locked and the control depended upon the steering alone. Plat B contained 1366 plants, twenty-one of which were covered, four broken off and nine plowed out, constituting a total damage of 2.5 per cent. The plants covered cannot be charged to the absence of the gang shift; so the final damage is eight to thirteen in favor of the shifting method. This margin is very small; and it cannot be considered as an average until it is augmented by data from different fields and with different operators.

Better control was secured by using the gang shift on the cultivating outfit operated in this work. However, the use of the shifting device seriously affected the steering on cross slopes, and the shifting latch consumed time on the turns. The gang shift, to be successful, must not throw an extra burden upon the operator when operating on cross slopes; it must be self-centering for the shift latch, and it must be as simple as possible.

Controlling the tractor and cultivator by means of the steering gear alone proved much easier for the operator, although the control was not as effective. With a steering gear of proper sensitiveness and with properly mounted cultivator gangs, the non-shifting cultivator should do as good work as the shifting type of cultivator. The general-purpose tractor to be used with a non-shifting type of cultivator requires a steering gear with a low ratio and corresponding quick response in its normal center position, this ratio increasing as the steering angle increases, giving the necessary leverage for certain control on the sharp turns. This type of steering gear, with the gangs mounted forward of the front wheels, should give adequate control coupled with ease of operation, and be simple in mechanical construction.

The standard equipment of eleven shovels on a two-row cultivator is unsatisfactory in a heavy soil with a rolling topography. The conventional shovel is the 3-inch double-pointed type. The spacing of eleven of these shovels is such that they fail to thoroughly stir the soil; and with a heavy rain, washing immediately begins in the furrows left by the cultivator shovels. Test plats were arranged for at the Virginia Agricultural Experiment Station and the following equipment used to determine this feature of soil washing: Fifteen 3-inch double-pointed shovels, eleven 8-inch sweeps, and eleven spearhead shovels. No erosion was evident on any plat, but the quality of the work varied. The fifteen 3-inch double-pointed shovels did the best quality of work with a crop damage of 1.7 per cent. Both the sweeps and spearhead shovels left the soil in a poor condition of tilth, and the crop damage was higher, being 5.5 per cent and 2.5 per cent for the sweeps and spearhead

Fig. 8. Left) "X" marks the skip resulting from a shifting of the lateral plane. At point "O" the row is covered by front wheel skid. The row "Y-Y" is ridged by the rear wheels. Fig. 9. (Center) This shows the packing effect of the rear wheels. Fig. 10. (Right) An illustration of the ridging caused by rear wheels under sidehill conditions

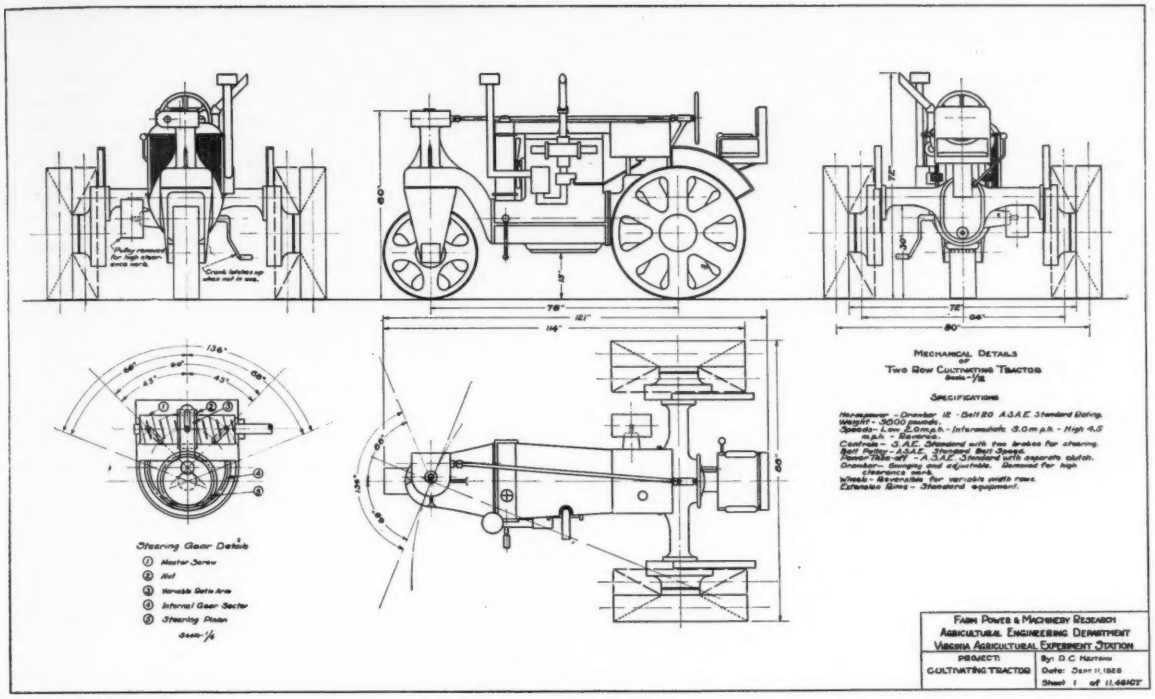


Fig. 11. General design of a general-purpose tractor to meet as nearly as possible the requirements indicated by the study

shovels, respectively. Considerable trouble was experienced in mounting the fifteen 3-inch double-pointed shovels because of the lack of space for the four extra standards. The gangs of a tractor cultivator should be designed to enable them to carry eight shovels per row whenever necessary.

There should be only one lifting lever, rather than two or more, especially where the outfit is expected to work in small irregular fields so often containing obstructions in the form of gullies, rocks, and stumps. It is an indictment of the engineering profession to require a farmer to work two or four levers every time he raises or lowers the gangs of his tractor cultivator. One lever is all that is necessary; and with the power from the tractor engine available a power lift is feasible.

The Tractor. The most important factor in the design of a successful general-purpose tractor is its steering. The tractor industry has made great strides in engine and transmission design and construction, but the majority of the control systems in use are crude. The automotive industry, in comparison, has developed the control system of automobiles, trucks, and busses to a high degree of perfection because women drive automobiles, and truck and bus owners look for a maximum of ton-miles and passenger-miles per day. The developmnt of the present type of automotive steering mechanism has determined the basic specifications of the ideal steering control system. These specifications are (1) an irreversible gear, (2) center point steering, and (3) correct ratio for precise control.

The degree of irreversibility desired in the steering gear depends upon the design of the entire steering system. If true center point steering is obtained, the gear need only be semi-irreversible; but if the steering wheels are mounted on a non-pivoting stub axle, a full irreversible gear is necessary. The ratio used will likewise effect a change in reversibility. The lower the ratio the more reversible the gear will be for a given type of gear, and the higher the ratio the closer the gear will aproach to irreversibility. The objective to be sought in the design of the steering mechanism of the general-purpose tractor is the greatest possible ease of steering consistent with the necessary precision of control.

Castoring the front wheels of the cultivating type of tractor will give quick response in dodging plants in crooked rows; but on a cross slope the castored front wheels will increase the tendency of the tractor to "nose" down hill. It is doubtful if castoring is desirable in the face of this trouble. A slight castor might be advisable, but this must be determined experimentally.

Stability is essential in the design of any farm tractor, but in the general-purpose tractor it becomes doubly important because of the work which the tractor is expected to do. Longitudinal stability is well understood and needs no further discussion than to mention that it is just as important in the general-purpose tractor as in the older and more conventional models. Lateral stability in tractor design has not received much attention, other than to keep the center of gravity low enough, and the tread sufficiently wide to prevent the tractor from tipping over on a side hill. In the general-purpose tractor lateral stability becomes highly essential because of the accuracy required in planting and cultivating. E. G. McKibben has stated the fundamentals of this problem[3]. In the general-purpose tractor, where stability means the ability of the tractor to travel in its prescribed course and to quickly respond to steering, the laws he has stated, which deal primarily with tractive stability, hold with equal force. A low center of gravity is as much an aid to satisfactory steering as it is to traction, and the side drift of a tractor on a cross grade is directly related to the height of the center of gravity.

When the operation is on a side hill, extremely high skid rings on the steering wheels are advisable, and skid rings on the drivewheels are worthy of trial. The use of skid rings, of the same height as the lugs, upon the drivewheels presents two advantages: First, greater stability upon side hills and, second, smoother operation on hard

[3]"The Kinematics and Dynamics of the Wheel-Type Farm Tractor," by E. G. McKibben, Vol. 8, Nos. 1-7 (Jan.-July, 1927).

road surfaces. The last item is very important in the general-purpose tractor, as it is frequently moved from field to field. Extensive hauling is not recommended with lugs and skid ring equipment on the rear wheels, but it will meet the normal requirements of the average farm.

Controlling devices on the general-purpose tractor must work with the least possible effort. Ease of steering has already been discussed; but the gear shift, clutch and brakes are also important. Because of the wide use of the automobile and the thought given to the automobile control system, it seems advisable for the tractor to copy this control. No sound argument can be made against its adoption as the standard control system for tractors. One slight change is suggested for the general-purpose tractor. Field experience with automatic differential steering brakes indicates a need for improvement in this phase of the control. Automatic steering brakes are convenient for the operator; but under many field conditions the braking is more efficient if directed by the human brain. Since the automatic brakes cannot be endowed with the power of reason, double foot brakes are suggested to enable the operator to assist the differential in its action.

The comfort and safety of the tractor operator needs careful thought in designing the general-purpose tractor. The large majority of present day tractors are safe for the operator, but not comfortable. A truck driver is given all the comforts of a coupe to insure his continued efficiency; yet the tractor manufacturers offer the farmer a tractor with a pressed steel seat that possesses neither back nor springs. They also offer a multiplicity of levers and pedals so arranged that disengaging the clutch and shifting gears is sometimes impossible without first getting off the seat, or, at least, sliding to its forward edge. Every tractor designer can profitably spend fifteen minutes with a rule, pencil, and pad of paper studying the layout of the driver's seat and the controls of the automobile in which he rode so comfortably to work. There are no deep mysteries involved in the comfort of the tractor operator.

The power take-off can be increased in usefulness by arranging it to be driven by a clutch separate from the master transmission clutch. In Virginia a large number of the spray rigs used in orchards are drawn by tractors, yet the spray pump is driven by a separate small gas engine mounted on the sprayer. The majority of spray rig troubles are caused by this small engine. With these rigs pumping 12 to 15 gallons per minute at a pressure of 300 or 400 pounds per square inch, the natural suggested solution is the power take-off. However, this solution fails with the present design because of the way in which this spraying work must be done. It is impossible to spray the trees as rapidly as the tractor travels, hence it is stopped frequently. This means that the power take-off driven sprayer stops, and a loss of pressure results. Usually the tractor operator merely pushes "out" the clutch during this short stop; but the operation of the sprayer with the power take-off is complicated, for, after the tractor is stopped, the gears are disengaged, the clutch then alone engaged, and the gears finally reengaged before starting the tractor. The same procedure is met with in other attempted power take-off jobs. The advantages of a separately operated power take-off clutch are obvious; but only one make of tractor has taken advantage of this adaptation.

Design. Two types of design are prevalent in the general-purpose tractor field, one based on the unit of two rows, and the other on three rows. Advantages are possessed by each and the ultimate type cannot be predicted. The two-row type of tractor is basicly a three-wheel machine. The steering wheel, whether in the front or rear, travels in the center of the two rows; and the drive-wheels, mounted on a wide-tread, high-clearance axle, travel outside of the two rows. The three-row tractor is a conventional four-wheel tractor with a high clearance and such width of tread as to enable it to operate between the outside rows of the three and to straddle the middle row.

The advantages of the two-row, general-purpose tractor are:

1. The present development of two-row implements. Many of the important farm implements are being used

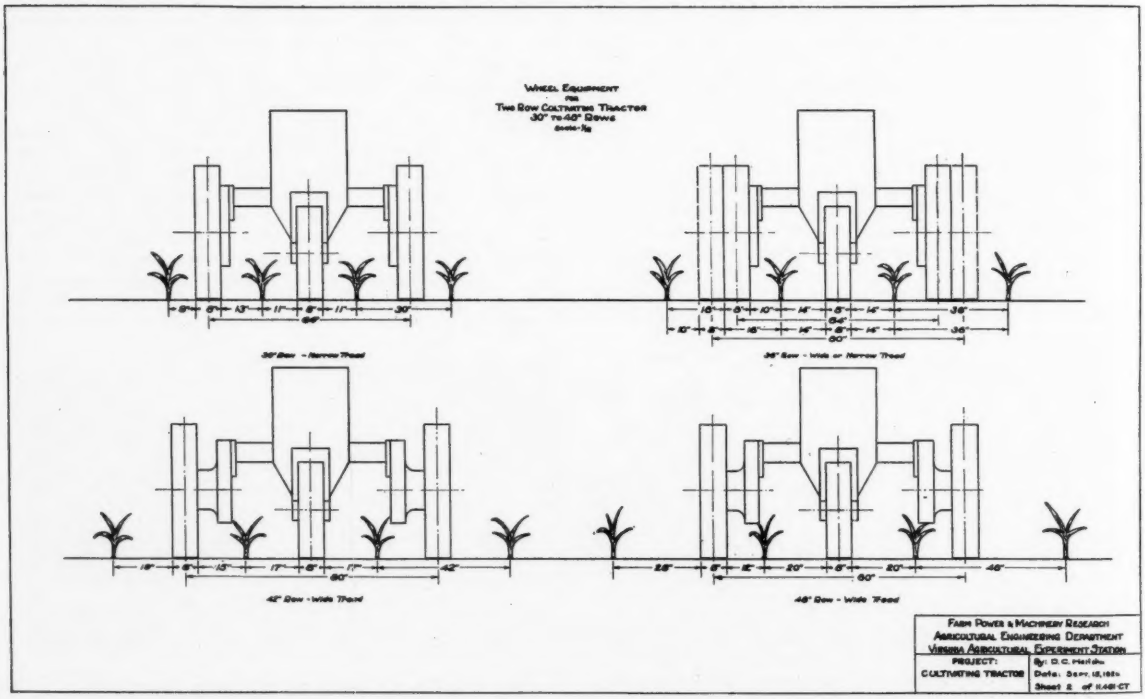


Fig. 12. Diagram showing the adaptability of the tractor shown in Fig. 11, to various row widths

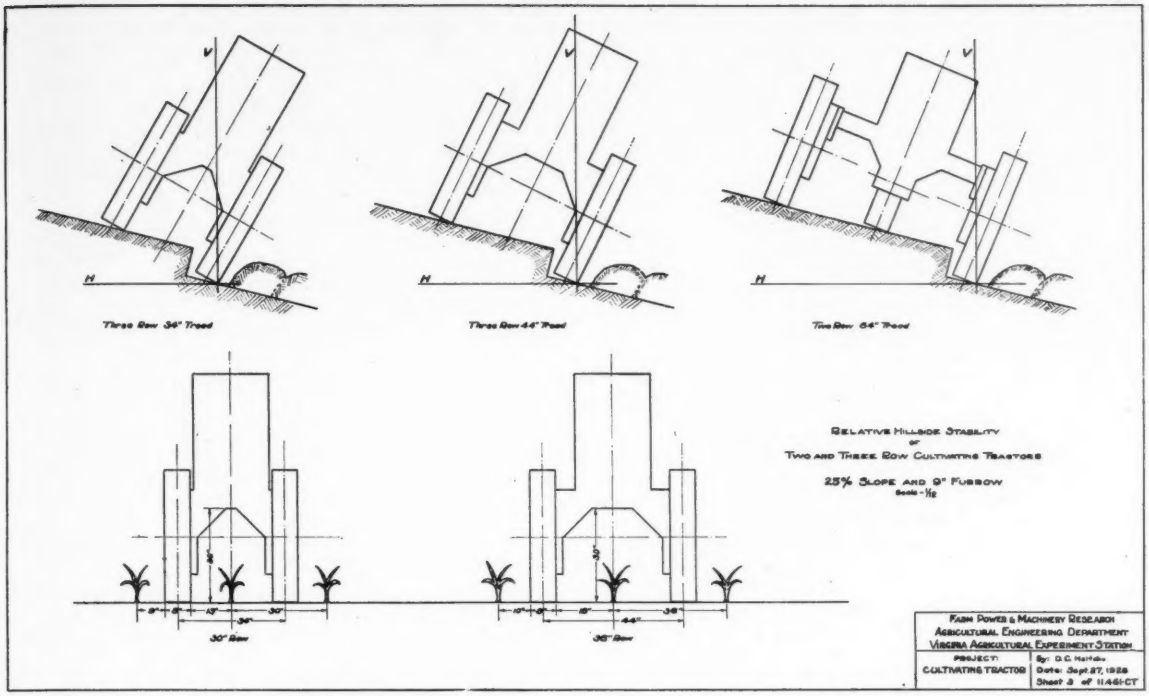


Fig. 13. Diagram showing the comparative lateral stability of the two and three-row types of general-purpose tractor

in the two-row size; in fact, the major basis of farm operations is the two-row unit. The fact that these implements and the technique of handling them are already present on the farm, is an advantage in favor of the two-row tractor.

2. The ease of enlarging to a four-row unit. In localities where the soil, crops and topography are suitable, the two-row tractor unit can readily be changed to a four-row unit. This means high production, a good load factor and continued use of the multiple of two rows.

3. Lateral stability. The three-wheel type of construction gives a low center of gravity and a wide tread.

4. Adaptability to a wide range of width of rows. With a 72-inch rear axle and reversible 8-inch wheels, it is possible to cultivate rows from 30 to 48 inches wide with this type of tractor, and by proper alternate spacings, rows of less than 30 inches can be worked easily.

5. Limitation, by rolling topography, on the number of rows that can be worked satisfactorily. In rough, small and irregular fields it is doubtful if any larger than a two-row unit can be operated satisfactorily. Topography is the limiting factor in the number of rows which can be worked at one time, and much of the most productive land in the East and South is very rolling. Terraces are another factor requiring consideration.

6. Restriction in the size of some implements because of the load imposed upon the tractor. Under some conditions it is necessary to work a single-row implement with a three-row tractor, resulting in a loss of efficiency. In other words, the multiple "two" can be applied to row crop operations more easily than the multiple "three."

The three-row general purpose tractor possesses the following advantages:

1. Simplicity and compactness of the four-wheel power unit. This involves many advantages for both the manufacturer and the farmer. It gives easier steering and eliminates side draft in plowing.

2. Better load factor under ordinary draft conditions. The proper loading of a tractor is very important if efficient operation is to be obtained. For this reason it is always desirable to keep the load factor as high as possible.

3. Suitability to standard 40 to 48-inch rows where the land is approximately level. This advantage involves such factors as cost, construction and service. The limits of this advantage lie in the width of row and in the topography, two very important items to consider in the design of the general-purpose tractor.

A SOLUTION

From the data presented, it is at once apparent that the general-purpose tractor design must be a compromise. Several commercial solutions present themselves for consideration. One method of meeting the situation is to manufacture a standard power and transmission unit, and fitting that with the proper axle it can be used as a two-row general-purpose tractor, a three-row general-purpose tractor, or a conventional industrial and road tractor. This plan will furnish a tractor to meet every need; but from the viewpoint of sales and service one tractor, which is a compromise in general-purpose tractors, is better.

The first item to determine in designing the general-purpose tractor is whether to use the two or three-row system. The advantages of the two types of tractors balance except for two points. These two points are stability and adaptation to various widths of rows. The two-row tractor is selected because it holds these advantages. If the two-row tractor is to be used, its size must be kept as small as possible. The overall height should not exceed 6 feet, and the major parts of the tractor, i.e., radiator, engine, fuel tank, etc., should be under 5 feet. The length need not exceed 10 feet, and the width is established by the rows to be worked. A maximum width of 88 inches, with a tread variable from 64 to 80 inches, will meet the requirements of working in rows from 30 to 48 inches in width. The vertical clearance is taken as 30 inches, while the horizontal clearance will vary with the width of row.

Fig. 11 presents a tractor meeting these requirements. The general specifications are: Belt horsepower, 20; drawbar horsepower, 12; (A.S.A.E. standard rating); weight, 3800 pounds; speeds, 2, 3 and 4.5 miles per hour; S.A.E. standard controls; belt pulley, A.S.A.E. standard belt

speed; power take-off, A.S.A.E. standard, controlled by a separate clutch; drawbar adjustable and swinging. The desired 30-inch clearance is obtained by removing the drawbar and pulley, while the crank latches up when not in use. The outstanding features of this general-purpose tractor are (1) the steering control, (2) comfort for the operator, (3) the reversible rear wheels to adapt the tractor to rows from 30 to 48 inches wide, and (4) stability.

The steering system has center point steering, which feature is secured by mounting one wheel with its center axis coinciding with the center line of the steering shaft. The steering shaft is controlled through the steering gear, which is of the irreversible variable ratio type. The essential parts of this gear are the master screw which controls the nut, which in turn oscillates the variable ratio arm through the pin and slot linkage. As the variable ratio arm cannot advantageously operate through an arc greater than 90 degrees, an internal-gear sector is attached to the variable ratio arm, this internal-gear sector operating the pinion mounted on the steering shaft. The ratio between the sector and pinion is such that the front wheel can be moved through the desired steering arc. The steering wheel, as well as the other controls, are mounted for convenience and ease of operation about the spring-mounted and upholstered seat after the standard automobile arrangement. The only change from standard automobile controls is the two steering brakes mounted for operation by the right foot.

How well this tractor is adapted to various widths of rows is shown in Fig. 12. The narrow, 64-inch tread enables the tractor to work in rows ranging between 30 and 36 inches. If necessary 28-inch rows can be worked with this tread. Rows from 36 to 48 inches can be satisfactorily worked with the wider tread of 80 inches. Almost any size of row outside of the 30 to 48-inch range can be worked by arranging the proper alternate spacings.

The comparative stability of the two and three-row types of general-purpose tractor is well illustrated in Fig. 13. The three-row tractor which will cultivate 30-inch rows is practically an impossibility, and the 36-inch, three-row tractor is not much better. However, by lowering the clearance slightly, and by careful designing to secure the lowest possible center of gravity, the three-row general-purpose tractor can be made to work 36-inch rows under any practical field conditions. The two-row tractor with its 64-inch tread is stable on slopes even steeper than the one shown. In most cases the stability of the two-row tractor will be greater than shown, as the wide tread or extension rims will be in use. Extension rims should be standard equipment with this type of tractor because of the narrow cultivating wheels used and the desirability of having spade lugs. The use of extension rims automatically widens the effective tread of the tractor, thus increasing its stability.

The cultivator attachment for this tractor is shown in Fig. 14. This cultivator meets the requirements of flexibility firm ground for the tractor wheels, cultivation of wheel tracks, ease of attaching, and simplicity of lift. These various factors have been fully discussed, and the cultivator is so simple that further explanation is unnecessary. The development of the planter unit for this tractor is simple, as it can readily be made for mounting upon the main draft bar of the rear cultivator gangs. The tractor industry should strive to give the farmer a one-man unit for every operation possible. Unit hitches and direct mounting will unquestionably be the next development in power farming equipment.

Obtaining an overall view of the general-purpose tractor problem emphasizes its complexity. The complications can be reduced by one method—standardization. The American Society of Agricultural Engineers can be of great assistance in this work if it will endeavor to further correlate the work of experiment stations and commercial firms, and establish standards or recommended practices in connection with the designs and operations of tractors. A general-purpose tractor cannot be built to meet all standards but certainly the development of this type of tractor will be aided by establishing standard row widths for various implements. Fixed widths would mean that standard tractor treads could be recommended. Standardization of

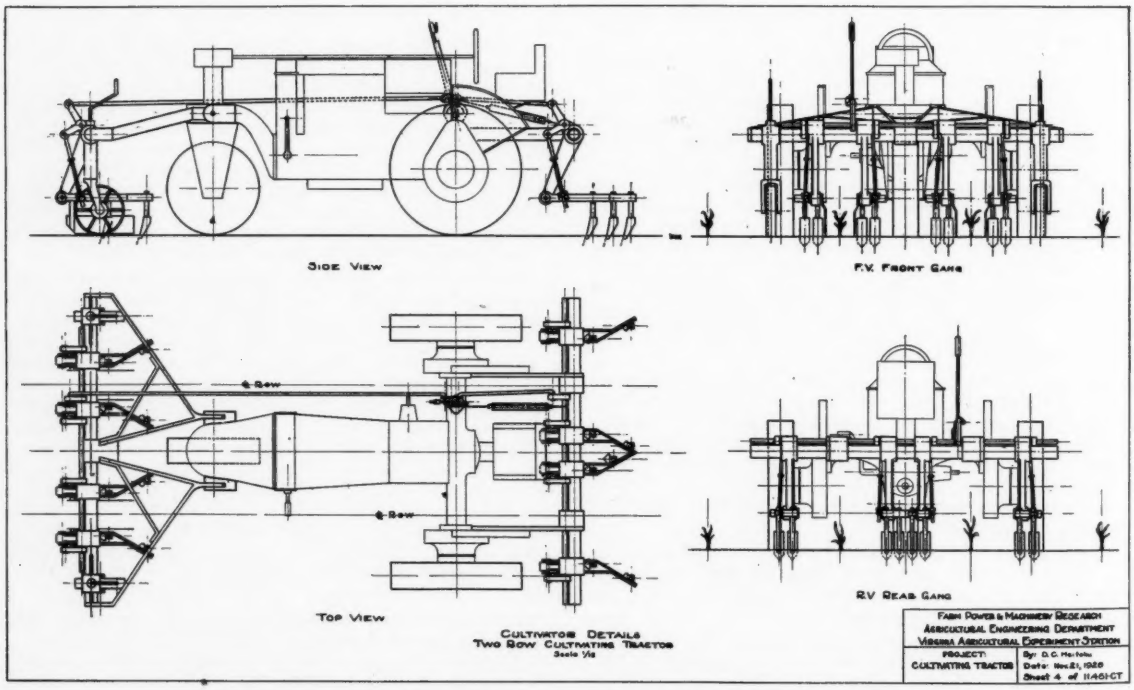
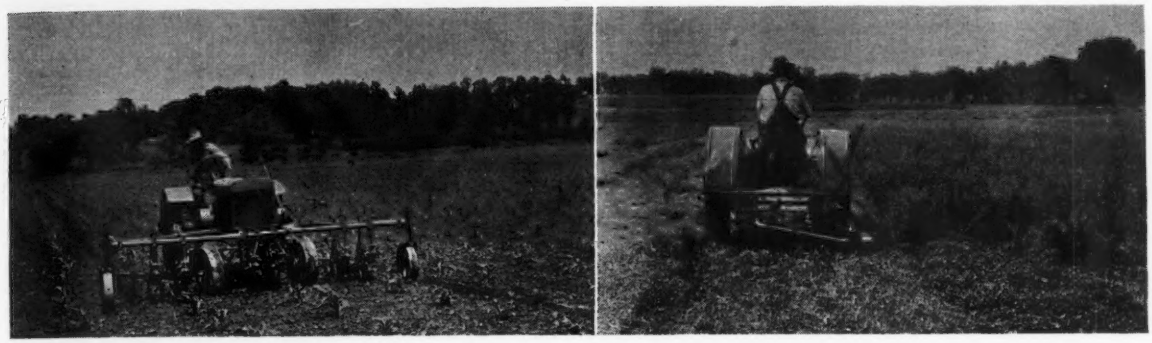


Fig. 14. Design of the cultivating equipment for use with the tractor shown in Fig. 11



(Left) This general-purpose tractor is equipped for cultivating three rows of corn at a time. The particular advantage of tractor cultivation is that it greatly speeds up this operation, thus permitting more thorough cultivation of the crop. (Right) The same tractor, as the one shown at the left, equipped with mowing attachment

controls, hitches for attachments, etc., should be effected; and as the development of this tractor continues, other phases of its design and construction should be standardized as rapidly as possible.

If every one of the organizations interested in this work will cooperate to their fullest extent, American farmers will have a successful general-purpose tractor within a very short period of time. Without cooperation the tractor industry can not give the farmer what the industry should give him, nor what it is capable of giving him.

Discussion

H. B. JOSEPHSON[4]: The question of row widths is undoubtedly one of the most troublesome problems for the general-purpose tractor designer. I might cite the conditions in Pennsylvania as regards row widths.

We have two major crops that require cultivation, corn and potatoes. (The relative importance of these crops from the standpoint of the general-purpose tractor we will discuss later.) The corn crop is uniformly planted in 42-inch rows. Not so with potatoes where a row spacing of 30 inches is most common. The farmers in Pennsylvania take great pride in high yields per acre and this is particularly true in case of potatoes. Most good growers aspire to membership in the "Four-hundred Bushel Club," an entrance qualification of which is to have produced 400 bushels of potatoes on one acre. This premium placed on high yields per acre has induced many growers to plant in rows 28 inches apart. Herein arises a conflict between high yields on the one hand and economical production on the other. Every machine operation after the crop is out of the ground is made extremely difficult on such a narrow row spacing. Not many general- purpose tractors have been used for cultivating potatoes in this state, but those that have are generally used on a 34-inch spacing. We have not recommended a narrower spacing for a tractor.

I believe that the potato crop of Pennsylvania must be included in considering the uses of the general-purpose tractor of 10-20 hp. or thereabouts. It is true that the corn acreage exceeds the potato acreage by about six to one. If, however, the tractor is used for weeding, cultivating and spraying, there will be at least three times as many operations throughout the growing season on a potato field as on a corn field. The better growers spray as often as ten or twelve times during the season. The power take-off makes the tractor well suited to the operation of a spray machine.

The narrow row spacing demanded by the potato growers of Pennsylvania excludes the general-purpose tractor as we have it today. Some compromise will have to be effected before the potato crop is successfully motorized.

Hillside work offers considerable difficulty to the use of the cultivating tractor in Pennsylvania and I think in general throughout the East. The rows are generally placed more or less along contour lines rather than up and down hill in order to check erosion. Even on moderate side slopes there is a marked tendency for the rear end of the tractor to creep down hill. This is particularly troublesome in cultivating when some of the shovels are placed in front and others in the rear, and when a machine is drawn behind the tractor, as, for example, a spraying machine. It seems that about the only way to keep the tractor parallel with the direction of travel would be to have the rear wheels on a slight pivot with respect to the tractor. The amount of turning necessary on these pivots would be very slight, and it might be made automatic in such a way that, when on the level, the wheels would be perfectly parallel with the tractor, while on a side slope the wheels would lead up grade in proportion to the steepness of the slope. The shifting might be accomplished automatically by a pendulum.

Mr. Heitshu has suggested foot pedals for the operation of the differential brakes as a substitute for automatic operation. I believe that differential brakes should be operated automatically on a tractor of short-turning radius. Such a machine if turned short without the use of the brakes is subjected to enormous strains. The non-automatic feature would lend itself to much abuse in the hands of a careless operator. Failure to apply the brakes upon turning as well as severe application of the brake when not turning would be exceedingly hard on the machine. Automatic brake operation tends toward foolproofness.

All steering and guiding, in my opinion, should be done through the steering wheel. Any type of dual control, as foot pedals to operate differential brakes or for shifting cultivator gangs, introduces unnecessary complications for the operator.

I endorse Mr. Heitshu's suggestion of operating the power take-off through a separate clutch. This would be a decided advantage especially for orchard spraying, and in all operations would be preferable to the present system.

In two farm operations in Pennsylvania there seems to be a need for a slower forward speed than is usually available on a tractor. I refer especially to harvesting potatoes by means of a potato picker. In heavy yields it is impossible for four men to gather the potatoes or pick out vines, clods and stones fast enough when operating the picker at the lowest speeds attainable with the present day tractor, or about 1½ miles per hour. The successful operation of a transplanter depends upon a very slow speed. I do not know how low this speed should be, but I think a speed as low as ¾ mile per hour or even less would be about right for these two jobs. Perhaps the tractor

[4]Agricultural engineer in charge of farm machinery research, Pennsylvania State College. Mem. A.S.A.E.

could be designed so that this extra low speed might be secured by securing some extra parts, possibly an extra pair of gears, on request.

On the subject of wheel equipment I am only going to say that we have found in our work with a general-purpose tractor at the Pennsylvania State College that the open wheel with the overrim equipped with spade lugs has given best satisfaction under all conditions. The overrim is in two parts and is fastened on the open wheel with only eight bolts.

For all heavy work the spade lug which was on an 11-inch rim far excelled all other equipment that we used on this tractor as shown by actual traction tests. The overrims are easily and quickly removed leaving the smooth open wheel for light hauling or traveling on the road. For potato work a special wheel was necessary giving the tractor a narrow tread to fit 34-inch rows. This wheel which has only a 6-inch rim and is equipped with cone lugs has been found most satisfactory for potato work where clearance between rows is limited.

R. I. SHAWL[5]: The general-purpose tractor with its ability to increase the amount of work done per man, especially in cultivating row crops, is causing considerable adjustment in land, labor, and machinery in sections where row crops are grown. I wish to present at this point one case which shows some interesting comparisons.

The department of farm mechanics at the University of Illinois has been making a study of the use of mechanical equipment in the production of corn. For this study a general-purpose, two-plow tractor is being used as the source of power. Both two-row and four-row planting and cultivating equipment has been used in this study. The tractor-machinery figures with the exception of planting, are based on an 80-acre field. The horse-operated machinery figures are taken from a standard for farm operations in Central Illinois compiled by the department of farm organization and management of the University. (See accompanying table.)

The totals in the table indicate that there is a considerable saving in man-hours by the use of the general-purpose tractor with two and four-row equipment. With costs figured as horse-man-hours, 25 cents; horse-hours, 12 cents; tractor-man-hours, 50 cents; and tractor-hours, 82 cents, there was a saving in cost of $1.31 per acre when four-row equipment is used in the place of the two-row planter and the one-row cultivator. However, with the two-row tractor cultivator, and the one-row horse cultivator, the cost was $5.76 and $5.84, respectively, indicating that the cost of the two methods was approximately the same.

These figures serve to indicate that if the general-purpose tractor is to compete with the horse in cost of production, it must have large capacity which makes it a saver of man labor.

Last spring one man, using the four-row planter and cultivator, planted and cultivated a 250-acre field of corn. The cultivation consisted of two times over, pulling two eleven-foot rotary hoes, and three times over with the four-row cultivator. The rainfall in May was 2.48 inches; in June, 4.65 inches; and in July, 3.69 inches. These figures indicate about an average amount of rainfall. We believe it is practical for one man to plan to take care of 250 acres of corn on well-drained land under the conditions stated above. The large field with rows one mile long naturally resulted in the saving of man and tractor hours. For instance, the rate of cultivation on this field was nearly one acre more per hour, for the first cultivation, than the first cultivation on the 80-acre field. This does not mean, however, that the 80-acre field is not an economical size field for this size equipment. It is doubtful if one two-bottom tractor could plow and prepare 250 acres of ground in the spring in time for planting, because the amount

[5]Assistant professor of farm mechanics, University of Illinois. Assoc. Mem. A.S.A.E.

Man, Horse, and Tractor Hours Per Acre of Corn Up to Time of Harvesting

Operation	Machinery* Horse-operated		Machinery** Tractor-operated	
	Man Hr.	Horse Hr.	Man Hr.	Tractor Hr.
Double disking stalks 1.00 acre per hr. (horse) 2.86 acres per hr. (tractor)	1.00	5.00	0.36	0.35
Plowing, 28-inch gang 0.50 acres per hr. (horses) 0.75 acres per hr. (tractor)	2.00	10.00	1.49	1.32
Double disking plowed ground 1.00 acre per hr. (horses) 2.66 acre per hr. (tractor)	1.00	5.00	0.39	0.39
Harrowing 4.0 acres per hr. (horses, four-section harrow) 3.9 acres per hr. (tractor, two 7-foot soil packers, and three-section harrow)	0.25	1.00	0.27	0.25
Planting corn 1.60 acres per hr. (horses) 4.66 acres per hr. (tractor)	0.63	1.25	0.24	0.21
Subtotal	4.88	22.25	2.75	2.52
Cultivating (three times) 1-row (horse) 75 acres per hr. 4-row (tractor) 3.88 acres per hr.	299	7.98	0.94	0.78
Total	8.87	30.23	3.69	3.30
Cultivatng (three times) 1-row (horse) 0.75 acres per hr. 2-row (tractor), 1.8 acres per hr.			1.78	1.76
Subtotal			2.75	2.52
Total			4.53	4.28
Cultivating (two tmes)			0.25	0.22
Rotary hoe twice over, 0,112 hr. per acre			0.62	0.52
4-row cultivator twice over				
Rotary hoe twice over, 0.112 hr. per acre			0.62	0.52
Subtotal			2.75	2.52
Total			3.62	3.26

All the above figures represent the actual tme in operation in the field.

*These figures are taken from standards for farm operations in Central Illinois by the Department of Farm Organization and Management, University of Illinois.

**Figures taken from work done by a "Farmall" tractor under the direction of the Farm Mechanics Department, University of Illinois.

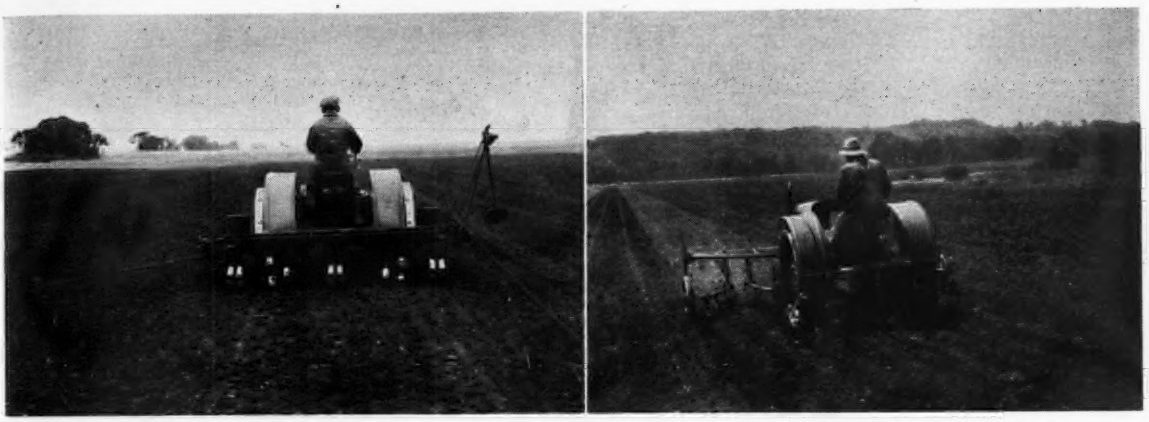
of rainfall, the temperature, and the wind velocity are too variable at that time of the year.

Illinois produces an average of approximately $329,000,000 bushels of corn annually. The growing of corn requires that more labor and power be available for growing and harvesting this crop than is necessary for the other work on the farm. The handling of the corn crop up to the time of harvesting is being quite well taken care of with the new developments that have taken place, but the harvesting of the corn by mechanical means is still a big problem. The present season has been an excellent one for the use of mechanical huskers, and many machines have been sold, including numbers of the two-row type.

Unfortunately weather and crop conditions must be favorable for the most successful use of the mechanical corn picker. It is therefore dangerous for the farmer growing a large acreage of corn to depend entirely upon the present machines to harvest his crop. The general-purpose tractor on corn belt farms will not fill the place it should until a thorough study is made of the adaptability of the corn and the picker to each other and a combination developed that can be successfully used.

J. BROWNLEE DAVIDSON[6]: It was suggested that my contribution should be a syllabus or outline on the general-

[6]Professor of agricultural engineering and head of the department, Iowa State College. Charter, A.S.A.E.



(Left) A general-purpose tractor with corn planting attachment, planting three rows at each trip across the field. (Right) The same tractor equipped with cultivating attachments and in use for the first cultivation of the corn crop

purpose tractor, which was presented a year ago before the tractor and thresher division of the National Association of Farm Equipment Manufacturers.

In this outline I have laid down the proposition that the general-purpose tractor would be a success if it could show an economic advantage and if it was proven to be practical. Referring to the matter of tractor economics in the regions growing row crops, it is easy to point out that at the present time about half the cost of tractor operation is due to interest and depreciation charges. That means a very heavy overhead, and if the overhead could be distributed over a larger range of use it would be quite an advantage.

I also pointed out the competition between mechanical and animal power. Whether you want to think of it that way or not, if use of mechanical power is to be extended it must displace the animal. So you must think of a machine that will displace the work the animal is now doing. Any system which calls for a duplicate power plant is evidently not economically sound.

Then I have undertaken to point out some of the essentials of the general-purpose tractor which will make it practical. Mr. Heitshu has already discussed these. It is absolutely necessary to have better control of the machine.

We have worked with various general-purpose tractors a good many years, and the manufacturers have sent us experimental machines. We operated a farm at Iowa State College for the purpose of trying out these machines, and I will make a few observations on the use of tractors on this farm.

In the first place, I would say the specially built planter for the tractor is a decided advance in the art of planter design. I do not think there has been much criticism of the corn planter during the past ten years in regard to accuracy of drop, if the machine was properly adjusted.

I believe the design of a new tractor for cultivating two rows is well advanced. We have not tried out two-row machines. Our work has been with the three-row and four-row machines. But so far as we can see, both machines are practical on such land as we cultivated. We do not have hills or very rolling land, and so we have not had side hill problems. It is easy to manage the machine satisfactorily, and the load is well within the capacity of the tractor.

I would like to mention one thing brought up by Mr. Shawl in connection with harvesting. We have a machine, a two-row snapper, and we are quite enthusiastic about it. It is carried on a tractor. We have worked it in mud where it would be impracticable to operate a pulled machine. If the farmer will accept a few more husks on the corn than he is used to, we think a real advance will have been made toward solving the corn husking problem.

Syllabus

The Future of the General Purpose Tractor

By J. Brownlee Davidson

The term "general-purpose tractor" is taken to mean a tractor adapted to the cultivation of intertilled crops and at the same time satisfactory for the usual tractor work of plowing and driving belted machinery. It is obvious that the present and future of a cultivating type of tractor will depend upon (1) economic advantage and (2) practicability. The following data and comments are intended to have a bearing upon these two questions:

1. A study of the source of the power used in agriculture reveals that competition for mechanical power for the farm is furnished by animals. (See U. S. D. A. Bull. 1348). Animals furnished 61.4 per cent of the 15,788,000 horsepower-hours used annually; gas tractors, 9.7 per cent, and all other motors, 28.9 per cent

2. A comparison of animal and mechanical power
   (a) Horse power
      (1) Large overload capacity (1000 per cent for short periods
      (2) Flexibility of size of units 2, 4,6 horse teams
      (3) Versatility, adapted to varying conditions
      (4) Less skilled labor required
      (5) Horse sense, self-guiding
      (6) Long life
      (7) Self-repairing and self-reproducing.
   (b) Mechanical power
      (1) Cheaper power
      (2) No rest period required
      (3) No fuel consumption while idle
      (4) Immune to hot weather and insects
      (5) Less weight per horsepower
      (6) More applicable to belt work
      (7) Large units easily controlled
      (8) Direct drive to machines using rotary motion, by power take-off.

A careful balancing of advantages would seem to indicate that excepting certain special situations or conditions the competition between animal and mechanical power resolves itself into a matter of cost and adaptability.

3. The cost of power is a large item, amounting to 15 to 30 per cent in the cost of producing crops

4. Principal items in the cost of power. (U.S.D.A. Bull. 1298)

   (a) Horse (600 hours annual service 16.5 cents per hour)

Feed and bedding	60.2 per cent
Care	11.2 per cent
Depreciation	6.3 per cent
Interest	6.9 per cent
Stabling	6.9 per cent
Other costs	8.5 per cent

(The important items of expense are feed and care, which continue while idle.)

(b) Tractor (3-plow, U.S.D.A. Bull. 1297).

Fuel and oil	34.0 per cent
Depreciation	41.0 per cent
Interest	9.5 per cent
Repairs and care	10.5 per cent
Other costs	5.0 per cent

(The important items of expense are depreciation and interest.)

(c) Duplicate power plants for the farm do not reduce the largest items of expense, feed and depreciation.

5. The cost of energy in the form of fuel and feed

One cent will purchase 10,500 B.t.u. in the form of kerosene at 12 cents per gallon.
One cent will purchase 5,250 B.t.u. in horse feed at 1⅓ cents per pound.
The thermal efficiency of an internal-combustion motor and an animal at work are about equal, i.e., 20 per cent.

6. The power in agriculture is used for the following purposes. (U. S. D. A. Bull. 1348)

(a) Field Work	Hp.-hr. annually in millions	Per cent	Per cent
Plowing	2500	32.9	
Tilling ground	1000	13.2	
Planting and seeding	400	5.3	
Cultivation	1000	13.2	
Harvesting	800	10.2	
Haying	900	11.9	
Miscellaneous	1010	13.3	
Total	7610	100.0	48
(b) Belt Work	4228		29
(c) Hauling	3550		23
Total hp.-hr. for all operations	15788		100

7. Area of the more important cultivated and non-cultivated crops. (U. S. D. A. Yearbook 1923)

Cultivated	Acres
Corn	104,158,000
Cotton	37,348,000
Potatoes	3,816,000
Grain sorghum	5,776,000
Tobacco	1,820,000
Total	153,918,000

Non-cultivated (not including hay)	Acres
Wheat	58,308,000
Oats	40,833,000
Barley	7,905,000
Rye	5,157,000
Total	112,203,000
Hay	176,055,000

8. The principal operations carried out with animal power

The following operations are cited in an Illinois Experiment Station Bulletin (No. 231) as non-tractor operations. It is recognized that some of these operations are carried out to a certain extent with tractors:
(a) Cultivating row crops
(b) Planting corn
(c) Husking corn
(d) Mowing, raking and loading hay
(e) Hauling bundles to thresher and ensilage cutter.

The tractor has had a decided influence upon the number of horses kept on farms. In Iowa a survey in 1926 reported 16 acres of crop to one horse on farms where tractors were not used and 22 acres of crop per horse on farms where tractors were used.

9. The number of tractors needed if row crops could be handled with tractors

Number of farms in U. S.	6,371,617 (1925 Census)
Improved land in all farms	503,073,000 acres
Number of tractors	506,745 (1925)
Acres per tractor	1,000

One tractor to each 125 acres of improved land would require an increase of 800 per cent in the number of tractors

10. Types of farm power plants
(a) All horses
(b) Tractor and horses
(c) Tractor and motor cultivator
(d) General-purpose tractor.

11. Some requirements of a cultivating tractor
(a) Cultivating equipment
(b) Width of track to fit rows
(c) Clearance to straddle row crops (24 inches minimum)
(d) Capacity, large enough for heavy tillage, light enough for cultivation. Must have power for two 14-inch or two 16-inch plow bottoms
(e) Ease and precision in control

These requirements are in addition to those of any good tractor.

12. Drawbar pull required (estimates)

	Pounds
(a) Two-bottom plow	1500
(b) Two-row planter	450
(c) Two-row cultivator	600
(d) Three-row planter	675
(e) Three-row cultivator	900
(f) Eight-foot double disk	1200
(g) Eleven-foot grain drill	1000
(h) Ten-foot grain binder	820
(i) Corn picker	1400

13. Some shortcomings of some cultivating tractors that have been designed

(a) Not easy to control
(b) Inconvenient to attach equipment
(c) Require skilled operators.

14. Possibility of changing cropping system

(a) Changing width of rows to permit standard tractor to travel between rows.
(b) Use of tillage implements such as the rotary hoe and weeder to replace cultivator for at least a part of the cultivation.
(c) Growing substitute crops.

15. Experience with a general-purpose tractor.

Man and tractor hours, 1927—104 acres

Operation	Total hours	Man-hours per acre	Tractor hours	Fuel per acre, gal.
Double disking	26.80	0.26	26.80	
Plowing	123.90	1.17	113.50	
Double disking and harrowing, 15 ft.	25.10	0.24	25.10	0.623
Planting, three rows	45.58	0.44	43.25	0.720
Harrowing, 38 feet	8.00	0.08	8.00	
Four cultivations	169.58	1.64	155.58	2.920
	398.86	3.83	372.23	

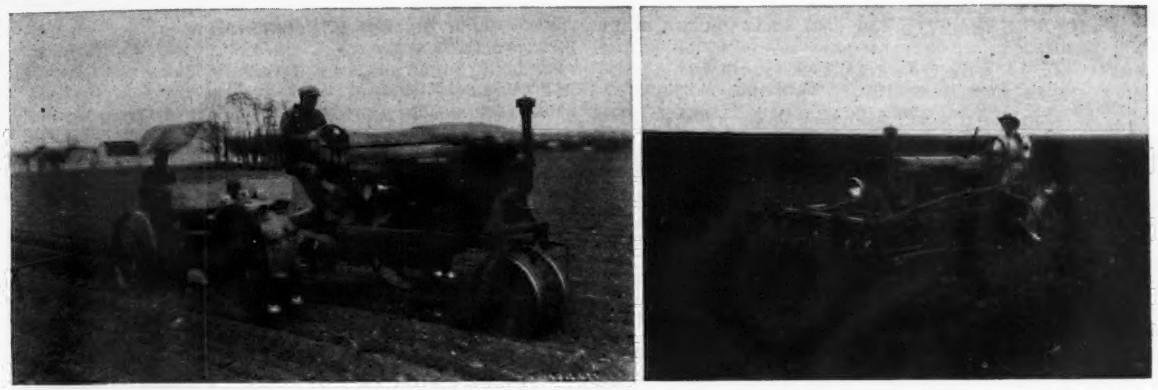
Four cultivations on 104.08-acre field, 1927. Three-row tractor cultivator

Cultivation	1st	2nd	3rd	4th
Fuel, gallons	80.00	85.00	73.00	63.00
Total time, hours	51.75	45.42	43.92	28.30
Tractor hours	47.00	41.75	41.17	25.66
Acres per hour	2.01	2.29	2.37	3.69
Acres per tractor hour	2.22	2.50	2.53	4.05
Fuel per acre, gal.	0.769	0.813	0.69	0.63

H. E. McCRAY[1]: The fundamental requirements of a general-purpose tractor, bearing in mind that these must be from the designer's standpoint, are a simple, compact, light-weight machine that will do the greatest possible number of farm operations on major crops, with a quality of work above that for existing horse-drawn standards, covering the greatest possible number of acres per hour, with the least possible manual labor and physical discomfort to the operator, at the lowest possible or practical cost per hour (considering the initial cost, the operating cost and the cost to maintain), with a manufacturing cost that will pay a reasonable profit on the large investment necessary to produce this sort of machine economically with modern mass production methods.

Those are what we believe to be the fundamental requirements of a general-purpose tractor from the manu-

[1]Chief engineer, John Deere Tractor Co. Mem. A.S.A.E.



(Left) Glenn Hunt, a Nebraska farmer, produced 120 acres of seed potatoes in 1927 entirely without horses. With the general-purpose tractor and two-row potato planter shown in this picture he was able to plant potatoes at the rate of 18 to 20 acres in a ten-hour day. (Right) This picture shows Mr. Hunt cultivating his potatoes at the rate of 15 to 25 acres a day, replacing two to three men and four to six horses

facturer's standpoint. The tractor design is completely settled by the work it has to do. The tractor alone is of no value whatever until you hitch an implement on it and start to work. The implements will fix the size and general type of the tractor.

As to the power requirement, Mr. Heitshu is in Virginia and we were in Iowa and we never got together on it, but I don't think we could have checked any closer on it if we had. We obtained our information through engineering and sales channels rather than the agricultural colleges and it checks very closely with his, as it should, of course.

The following are some of the things we have learned in three years of experimental work:

1. An absolutely flexible unit or set of units must be used for multiple-row cultivation. The larger the equipment, the more flexible is must be. With a completely flexible piece of equipment you will find it possible to handle almost any sort of rolling ground.

2. You must have the proper location of hitch and gage points on the tractor, whether you attach the implements either ahead, under or behind.

3. Where accuracy of control is necessary, it is very desirable to have the implement integral with the tractor. Where you do not have any necessity for accurate control that is not the case. (Mr. Heitshu spoke of automobile steering as being a criterion. The requirements on a general-purpose tractor are much more strict than on automobiles, because when cultivating down a row the first time you have a limit of plus or minus one inch in half a mile. I would like to see anybody steer an automobile in those limits.)

4. Complete comfort and convenience of the operator. That includes a comfortable seat, fenders, shields, a platform where he can change his position, and vision sufficiently good so he doesn't have to crane his neck but can sit in a normal position and have easy steering. Incidentally, design of steering ratio is not affected by the degree of reversibility or irreversibility. It is fixed to a 180 or 210-degree rotation of the steering wheel by the fact that only a little over a half turn is possible without letting go of the wheel.

The elimination of the use of tractor drivewheels as gage wheels is desirable. If you don't believe it, try to get your tractor fished out of some soft ground after it has been "lost" with an integral lister attached.

Power requirements are not two-thirds of of a three-plow machine, but about three fourths, on account of the small difference in weight of the combined unit of tractor and tool in two-plow and three-plow machines.

GEO. W. IVERSON[8]: About six years ago I made a study of the possibilities of the general-purpose tractor, which was published in the 1922 Transactions of the Society.

First of all, I assumed that the general-purpose tractor was first correctly designed to do general-purpose work. Then I compared the amount of work that could be done by a standard four-wheel two-plow tractor and this general-purpose tractor on a 200-crop-acre farms, this farm consisting of 80 acres of corn, 40 acres of oats, 40 acres of winter wheat, 20 acres of clover hay, and 20 acres of pasture. The four-wheel standard tractor could do 2230 hours of work, leaving 3130 hours that must be done by horses, or approximately half the work had to be done by horses. I also determined from that study that with the standard four-wheel tractor you could not eliminate many horses, because the peak load for horses came during the cultivating season.

With a general-purpose tractor, capable of doing row-crop cultivation, the 3130 hours by horses was cut down to 1390 hours, with the tractor 4870 hours of labor. Since that time there have been developments in certain machines, particularly corn husking machinery and haying machinery, which permit a still further reduction of horse labor.

I believe I am safe in saying that, at the present time, the average corn belt farm can be operated without any horses and do the work entirely with mechanical labor. From the standpoint of economics, as Mr. Davidson pointed out, the all-purpose tractor will do a cheaper job for horses. It is a well known fact that you can produce a horsepower with a gasoline engine cheaper than you can with horses using hay and oats as fuel. Just how much difference there would be would depend, of course, entirely on local costs, but I know from my own studies that it is a fact and that it can be done.

With the present design of all-purpose tractors, there are two general types that Mr. Heitshu has mentioned. He has not, however, mentioned one design which incorporates the two general types. He mentioned the four-wheel type and the three-wheel type. There is a type which incorporates the two types, so that either one or the other can be used, depending upon the kind of work that is required.

I want to point out the fact that at the present time an all-purpose tractor can and will be successful, and you can produce an all-mechanical farm in the corn belt or in practically any farming operations we have in the United States.

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[8]Divisional sales manager, Advance-Rumely Thresher Co. Mem. A.S.A.E.

R. H. DRIFTMIER[9]: The field of usefulness of the general-purpose tractor in Kansas seems to be in that portion of the state where general or diversified farming prevails. This area includes both the corn belt and the general farming areas of eastern Kansas. About 55 per cent of the corn, 50 per cent of the alfalfa, 75 per cent of the potatoes, and 54 per cent of the oats grown in the state are produced by the thirty-five counties which comprise these two areas. The average size farm per county in the corn belt varies from 55 acres for Wyandotte County to 232 acres for Pottawatomie County, with a general average for the eighteen counties of 171 acres. The farms in the general farming area vary from 122 acres for Johnson County to 214 acres for Woodson County, with an average of 159 acres for the seventeen counties. About 77½ per cent of all the farm land in the two areas is improved.

A good crop rotation for northeastern Kansas and the better farm lands of southeastern Kansas, which does not include the white ashy lands, carries a four to six-year rotation of corn, oats and sweet clover, or corn, oats and alfalfa. All of these crops can be wholly or partially cared for by the general-purpose tractor. In the Kaw Valley the general-purpose tractor should find a place in economical potato production. In corn production, 45 per cent of the cost of producing an acre of corn in Kansas is chargeable to power and labor, where horses furnish the motive power. These power and labor costs can be greatly reduced by the utilization of power machinery and cultivating tools which will cover greater acreages per day with the same efficiency in moisture conservation and weed control.

In the production of hay, investigations at the Kansas State Agricultural College indicate that with a general-purpose tractor hay can be mowed and raked in one operation at a cost of 0.486 tractor-hours per acre, and then bucked to the baler with 0.491 tractor-hours per acre, the man-hours equalling the tractor-hours in each case.

The contribution that the general-purpose tractor and its operating equipment may offer to efficient and profitable crop production in Kansas resolves into a study of farm conditions and agricultural production for each section, locality and farm.

D. B. LUCAS[10]: There are over five hundred million acres of improved land in the United States. Approximately one-half this area is plowed annually at a cost variously estimated at around half a billion dollars. Because of this enormous investment, plowing and the other processes in seedbed preparation require first consideration in the design of a tractor for general farm use. Plenty of power and high tractive efficiency are assumed as necessary features of a successful plowing outfit. Manufacturers have exercised much care and pains over more than a score of years to produce a machine specifically designed to meet plowing needs, and to fit into such other farm practices as do not call for radical modifications of that design. Today the market affords a choice of many makes and sizes of tractors, almost any one of which is suited to average plowing conditions. Characteristic of these power units is (1) the tendency toward high power, (2) compactness with low clearance, (3) plowing speeds ranging around 2½ miles per hour, (4) rigid construction with fixed dimensions, and (5) a price somewhat proportional to merit so that competition is keen.

The production of row crops permits the continuation of thorough surface tillage. Because of the conditions involved, the cultivation of such crops has been peculiarly adapted to the use of horse power. The relatively narrow path which a horse may follow, the light draft of common cultivators, the ease of guiding horses in rows, the ease of starting and stopping, and the fact that horses have seldom been charged with serious packing of the soil, have been factors in keeping horse power predominant in cultivation. In order to supplant horse labor during the growing season the tractor must be adapted even more advantageously. The shape of the power unit should be narrow to pass between the rows, or what seems more practical, the clearance under the machine should be high to permit straddling of the rows. This requires an arched frame or the use of extremely high wheels. Because of variations in row widths the tread of the tractor needs to be adjustable. Of secondary importance are those factors which contribute to efficiency and convenience. Speed increases the capacity of the outfit. Ease of guiding and turning around at the end, and ease of starting and stopping are essential in order to gain favor over methods employing horses. Lightness seems desirable, though the actual dangers of soil packing are the subject of controversy. In all, the essential features of a power cultivator are vastly different from, and in some ways in opposition to, those which characterize the plowing unit. We are confronted with the problem of developing or recommending one power unit to adequately fill nearly all of the farm needs in the field and on the belt. Extreme optimism would seem evident in any predication to the effect that a complete solution is near at hand. Nevertheless there is ample need for spending considerable effort in improving present conditions, and, as one agricultural engineer has expressed it, the results may be like the general-purpose cow, which does not fill either purpose completely. Yet

[9]Associate professor of agricultural engineering, Kansas State Agricultural College. Mem. A.S.A.E.

[10]Associate professor of agricultural engineering, Rutgers University. Assoc. Mem. A.S.A.E.

(Left) On Babson's Four Pine Farm near Hinsdale, Ill., a general-purpose tractor is used for operating a hay baler. (Right) The general-purpose tractor is especially adapted to hauling wagon and loader in gathering hay in the field. In fact, it is well adapted to all haying operations from mowing to baling

there is a proper place for such a cow, and there is a place for such a tractor.

New Jersey holds a leading place in the production of truck crops and furnishes a ready market for the better makes of light garden tractors. Manufacturers and agricultural engineers are repeatedly called upon to furnish or recommend a small power cultivator which is capable of plowing. The problem is in many ways similar to that of the general purpose field tractor, only perhaps more exaggerated. Those farmers who operate large enterprises ordinarily have several power units suited to various uses. Plowing is done with a field tractor or horses. Cultivating of the narrower rows may be done with a group of small power cultivators or even by hand. There are light power outfits on the market which are admirably suited to this highly specialized work. Unfortunately, perhaps, there are many smaller truck farming enterprises where neither the plowing nor the cultivating work alone justifies the purchase of a separate power unit. The only immediate solution seems to be a power garden cultivator which will plow satisfactorily. The problem in our present discussion is similar except that we seem to need a plowing tractor that will cultivate satisfactorily. Returning to the garden tractor, it appears impractical to try to market a machine which has enough power and weight for acceptable plowing, because such a machine is costly, and usually is awkward to manage in narrow row cultivation. Reports from New Jersey dealers indicate a trend in demand from the extremely light cultivator toward the intermediate size of tractor which can plow a narrow, shallow furrow. In other words, a compromise is being effected, and in a similar way a certain amount of compromise may be necessary in adapting a tractor to the field plowing and cultivating requirements of the general farm. There must be some compromise between the rangy, fast, light machine for cultivation and the compact, high powered machine with traction for plowing.

The possibilities of overcoming differences in the field requirements of a general-purpose tractor by a rearrangement of the running gear are dependent on the ingenuity of the manufacturer and the mechanical ability of the farmer. Garden tractor and power cultivator designers have made use of the swinging arch and extra sets of wheels in order to get a high clearance for cultivation and a low hitch for plowing. Weight may also be added when increased traction is necessary. The principal objection to complicated adjustments has been that the farmer lacks either the time or the mechanical inclination to make them work properly. However, a consideration of the ease with which such a machine as the grain binder may be adjusted for transporting purposes seems to diminish the obstacles confronting adjustments of the tractor set-up. I am inclined to think that if a salesman or manufacturer would tactfully call a farmer's attention to the convenience of setting the tongue and transportation trucks under the present day binder, he would find a greatly reduced sales resistance toward a reasonable amount of tractor adjustments. Flexibility in the assembly and set-up of the general-purpose tractor seems to be almost essential to proper adaptation for general usage, though sturdiness must be maintained. At any rate, if farmers must be depended upon to furnish a certain amount of mechanical talent in handling a general-purpose tractor, they will eventually do so. Farmers today drive automobiles, overhaul engines, build radios and manage a line of mechanical apparatus which would at one time have been far beyond their interests and abilities. The adaptation to any particular type of management may have to be gradual, though ultimate success will not be lacking through weakness of the farmer in mechanical operations.

Just what will be the need for a general-purpose tractor will depend on the trend in agricultural machinery and practices. Present types of tillage equipment may give way to a new line having still different power requirements. But of even greater importance is the managerial side of farming. There is much discussion at present as to the possibilities of an increased proportion of large farms. General-purpose tractors belong essentially to the smaller enterprises. The big farmer can better afford a power unit for each major operation having different requirements, than he can afford one general-purpose unit which may not be entirely adequate for any one operation. In large-scale industries a slightly improved piece of equipment which operates daily may displace a partly worn machine, and profits can be demonstrated beyond a doubt. In contrast, the high charges which a small farmer must credit to interest and to depreciation during idle periods tend to minimize the advantages of small improvements in the operating efficiency of a new machine. Thus, while the big farmer may find it profitable to have both a field tractor and a power cultivator because operating efficiency is relatively important to him, the small farmer must be governed more by the interest and depreciation costs during idle periods. He can better afford to do both the plowing and the cultivating operations at a slightly decreased convenience and efficiency, if necessary, than to pay the difference for an additional power unit. The successful general-purpose tractor does not need to perform all tasks at an efficiency comparable to the specialized power units, but it should not allow this inefficiency to become too great to be compensated by the investment advantages.

One of the outstanding hindrances to a more extensive use of farm tractors has been the fact that the average tractors has not displaced enough horses. If the general-purpose tractor can handle all of the tillage and other field operations and belt work, it will still be only a partial substitute for horses. Hauling light loads or making long trips to markets usually can be done best by horses or a truck. In New Jersey, where marketing occupies a leading place in the farming schedule, trucks are in general use. Good roads and the frequency with which trips are made to market, carrying perishable goods, contribute to the popularity of the truck in this state. The high cost of feed on the other hand has made it expensive to keep horses the year around. Reports from local dealers indicate that tractor sales are increasing in New Jersey and that power cultivators and general-purpose tractors are rapidly coming into use. From the manufacturer's standpoint it is indeed promising to note the advance made by one prominent general-purpose tractor. This machine is already selling as rapidly as the more standard designs of tractors, even though extensive advertising, publicity and sales pressure have been lacking. It is a rare event in business to experience a demand so great, or a commodity so satisfactory, that extensive sales are made without resort to thoroughly organized and skillfully conducted selling campaigns. It means something for a tractor to win its own way. New Jersey farmers are taking on the general-purpose tractor, and every improvement that is made in its adaptation to general uses will hasten the day of the one tractor farm aided only by a team or truck.

Stationary Spraying Systems in West Virginia Orchards[1]

By F. D. Cornell, Jr.[2] and H. L. Crane[3]

THE use and development of a stationary system of orchard spraying has created widespread interest among orchardists. They see in it a possible solution of the problem of a more satisfactory, efficient and economic means of controlling orchard insects and diseases.

The only published results of experimental work with stationary spraying systems now available have been issued by the California and Washington agricultural experiment stations.

Results of the investigational work conducted at the California station on stationary spray plants have been published in California Bulletin 406. This bulletin, by B. D. Moses and W. P. Duruz, sets forth some advantages of this type of system for California conditions. It describes the individual units of the system and the methods of installation. In addition, field observations and results of field tests are included.

On the large percentage of systems, electric motors are used as a source of power. The effect of various factors on voltage drop are shown. Tests also showed 1 to 1½-inch mains and ¾ to 1-inch laterals to be most satisfactory. Pressure tests were made with varying numbers of nozzles open to determine the relation between pressure drop and the number of nozzles. Installation costs were found to range from $29.21 to $106.19 per acre, and operating costs to be from $5.04 to $12.69 per acre for a single application.

The Washington station has carried on some investigational work with stationary spray plants. Results of the work have been published as Washington Bulletin 212. In this bulletin, by H. L. Garver, the units and set-up of the system are described. In Washington, as in California, electric power is used extensively on stationary spraying systems. Rather extensive tests were made on the effect of pressure on the atomizing and the carrying distance of the spray, the results of which are included in the bulletin in tabular form. Data on installation and operating costs are also given.

West Virginia orchardists have for years followed the common method of spraying by using portable spray rigs. On the larger orchards several spray rigs, tank wagons, a large number of mules, and a large personnel are required to put on a spray. Breakdowns, delays, maintenance, and housing of equipment, high feed costs of keeping mules, and high labor costs cause many to stop and consider, if perchance some effective, efficient, and more economical system of orchard spraying might not be employed.

During the past eight years, as a result of much consideration by individual growers, six orchardists have pioneered the way in the state by installing a total of nine separate and complete hydrant or stationary spraying systems in their orchards. These men have gone through the experiences of trial and error in working out the details of a successful system for West Virginia conditions, and their contribution to the progress of the development of a more efficient and more economical system of orchard spraying, if such it proves to be, should receive the hearty approbation of all orchardists in the state.

There are certain obvious features of this system which recommend it as worthy of every serious consideration. Probably the most outstanding of these is the timeliness of the spray. With the hydrant system, the spray can be put on when it will be most effective, regardless of the condition of the soil. With sprays such as the pink spray and the codling moth spray, the season for effective application is short. With the hydrant system these sprays can be applied at the proper time, since soil and climatic conditions are not limiting factors.

Then, too, there are possibilities of great economies to be effected in the use of stationary spray systems. The points which suggested to these pioneer users the possibilities of saving were the facts that a spray could be put on with a smaller personnel; there was greater crop insurance since the spray could be aplied at the proper time and more thoroughly; costly horses and mules could be eliminated; and perhaps maintenance costs of equipment lowered. It was a consideration of these problems which prompted these growers to install these first systems and bear the brunt of much costly experimenting in an effort to find a more ideal type of orchard spraying equipment.

This study of the stationary spray plants in the state has as its purpose, therefore, the making available for the growers the information obtainable regarding the details and costs of installation, the handling of the system the year round, and the efficiency and economy of the hydrant system as compared with the portable method of spraying for both large and small orchards.

This report presents facts, figures, and recommendations as they were obtained from the owners of the hydrant systems. These recommendations should be of interest and value as they are made after long and often costly experiments and trials with various items of equipment within the system. All of the systems studied, with one exception, had been installed for at least two spraying seasons.

The Water Supply. In interviewing users of the hydrant systems each one particularly emphasized the absolute necessity of having available a plentiful water supply. The stationary system requires considerable quantities of water for operation and the water must be available for use to carry on the day's spraying. The quickness of putting on the spray, the quantity applied per tree, and the flushing of the lines with water all make heavy demands on the water reserve. The ideal location for the water supply is above the spray plant so that water can be obtained at the mixing tanks by gravity. If there is no source of supply so located, it is advisable to pump water to a tank or reservoir at the desired elevation rather than try to locate the plant near the source of water and then have to pump spray liquid up hill under heavy pressure. The advice of present owners is that the force of gravity should be employed in every way possible. It is advisable, too, to have large pipes from the supply to the mixing tanks so that tanks can be filled quickly.

Location of Plant. Most of the orchards in West Virginia are, in part at least, located on well-defined slopes or on rolling land. As a consequence, the main plants of the hydrant systems now in use in the state, with two exceptions, are located at high points in the orchards. Thus gravity pressure is taken advantage of and such high pressures need not be maintained at the pumps. Another advantage of this plan of location is that the various parts of the systems are working under lower pressure, thus helping to insure somewhat longer life and lower maintenance cost.

One owner whose orchards are on opposite slopes has located his plant in the valley between, and pumps the

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[1] A preliminary report of a cooperative investigation by the Department of Farm Economics and the Department of Horticulture of the West Virginia Agricultural Experiment Station. Released for first publication in AGRICULTURAL ENGINEERING.

[2] Agricultural engineer, West Virginia Agricultural Experiment Station. Assoc. Mem. A.S.A.E.

[3] Associate horticulturist, West Virginia Agricultural Experiment Station.

spray liquid through mains running up either slope. This requires a much higher pressure at the pump in order to get a satisfactory pressure at the spray nozzle than in the cases where gravity is effectively utilized. In general, the recommendation is that the plant be located at a high point in the orchard making use of the advantages to be gained by gravity wherever feasible.

The Power Plant. The part of the hydrant system about which greatest interest centers is the central power plant, since the effectiveness of the separate items of equipment here determines in large measure the degree of success attained in using the stationary method of spraying.

From information obtained, an engine of sufficient power is essential to successful operation. This means that there should be sufficient reserve power so that the engine does not have to work at full capacity at all times. The type of engine may vary greatly so long as it is capable of developing adequate power. This is indicated by the fact that there may be found on the plants now successfully operating, engines varying in type and kind as follows: One 16-hp. steam engine, the engine being used for power and the steam also for cooking the lime sulphur; one Hercules 35-hp. gasoline engine; one Ford automobile engine; one Stearns-Knight automobile engine; one 10-20 International tractor; and one Edwards one-cylinder engine capable of developing 6 hp. On the only system where there seemed to be much difficulty from delays and breakdowns, a 4-hp. Novo engine was in use and was unsatisfactory as a source of power. In figuring the power necessary in this particular instance it was found that at least an 8-hp. engine would be required for successful operation. Thus it can be seen that the engine is a vital part of the system, although used automobile engines which had cost as little as $10 seemed to be performing admirably, illustrating that adequate power can be obtained at a low cost. The employment of used automobile engines, which can now be obtained at a very moderate figure and for which replacement parts are readily obtainable, opens an avenue of possibility in obtaining an engine very cheaply for stationary use which under such conditions should perform satisfactorily for a long period.

In most of the systems now in use, power in transmitted by having the pump geared directly to the drive shaft of the engine. On one small plant a belt is used satisfactorily. Also on one large plant, in which a pressure of 600 pounds per square inch is carried at the pump, power is transmitted by a belt. Either method of power transmission seems to give satisfactory results, although the positive gear transmission is preferred.

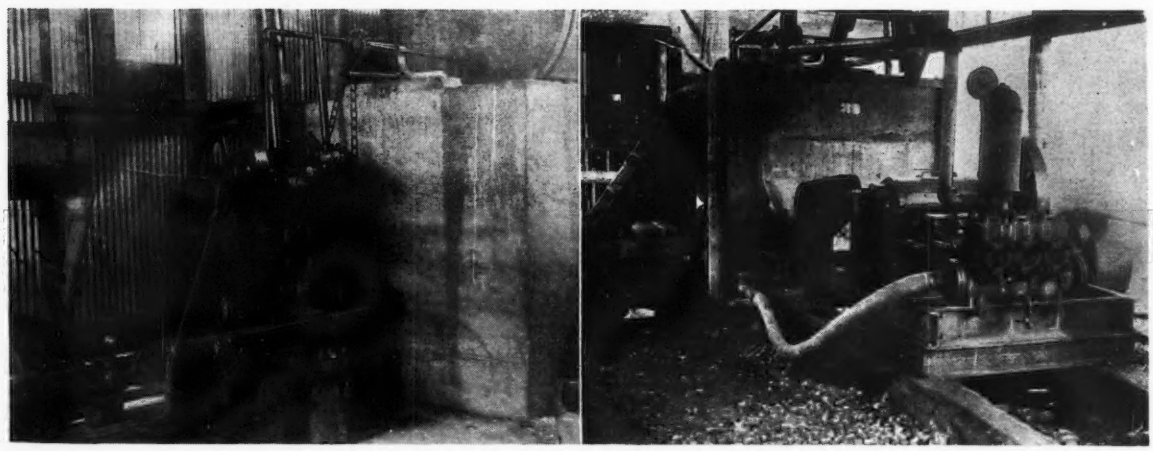
The Pump. The history of the development of a satisfactory pump for stationary spray plants is a very interesting one. On one of the systems now in use in the state, and incidentally one of the first if not the first such system in the East, several pumps were tried with poor success. Finally, one of the well-known pump companies built a pump to order to meet the specifications furnished by the owner of the system. This was probably one of the first pumps specifically built for use with a stationary spray system. The pump proved very satisfactory, and, with a few minor changes and replacements which actual operation revealed should be made, is still operating very effectively and shows no sign of serious depreciation after six years of service. This pump has been improved and refined by the company and a later model is now in use on two installations.

At present several of the leading manufacturers of spray pumps, realizing the increasing popularity of stationary spray systems, have developed pumps for this use which are highly satisfactory.

On the systems now operating in the state there are three Domestic "Giant" pumps. These are three-cylinder pumps. The first model has a 3-inch bore and a 12-inch stroke. The later model, of which two are in use, has a 4-inch bore with a 14-inch stroke. This pump is capable of delivering 80 gallons per minute under 500 pounds pressure. Two Bean three-cylinder spray pumps, delivering 16 gallons per minute under 400 pounds pressure, are giving complete satisfaction. On one plant a Myers "Bulldozer" pump delivering 10 to 12 gallons per minute under 300 pounds pressure is used, and on one plant an old portable spray pump is in use. The latter is a small plant, and the rig, although made up almost entirely of cast-off equipment, is serving 60 acres of orchard efficiently.

Since the pumps in the hydrant spray systems work under such heavy pressures, it is important that they be securely and rigidly anchored to a solid base in order to eliminate vibration and get the best results. The pump itself, in order to give long service and successfully withstand the high pressures without strain, must be very substantially constructed.

One point which is open to speculation among owners of hydrant systems is in connection with the pump. Most of the pumps now in use on the systems are special pumps for which replacement parts are not readily available. As yet no serious difficulties have been experienced due to breakdowns. About the only replacement costs on pumps thus far have been for new packing occasionally. However, the question of costly delay in case of serious breakdown is ever present and one owner suggests as a solution for this question a battery of smaller identical pumps any one of which could be cut out at any time leav-



(Left) Partial view of equipment comprising a West Virginia stationary spraying system. (Right) This picture shows tank and pump of a stationary spraying system serving 250 acres of orchard

(Left) View of a complete central plant of a stationary spraying system used for a large orchard. (Right) This small stationary spraying plant was made up largely from obsolete equipment

ing the others to operate. Since owners are having no pump troubles now they are worrying very little over this question.

The pressures under which the pumps operated varied from 300 to 600 pounds. The latter high pressure was necessary since the spray liquid was pumped up hill, a rise of nearly 400 feet. This gave a pressure at the highest point of about 290 pounds with the gun open. The gun had 7/64 discs and was on the end of 250 feet of ½-inch hose. The average pressure carried in the stationary spray systems is about 400 pounds.

Relief Valves. An efficient and reliable relief valve is necessary for proper protection to the system. A relief valve which fails to function properly may cause considerable damage as was illustrated in one case when several of the parts of one system in use in the state literally blew up due to a failure of the relief valve to operate properly. Although on one or two of the plants, several different makes and types of relief valves have been tried, there has not been enough thorough experimenting to determine definitely which type of relief valve is most reliable for use with the stationary spray system.

Strainers. In general a strainer so constructed that the materials are strained up through the screen rather than down is by far the more satisfactory. In a strainer of this type, the material taken out by the screen tends to fall away from the screen and settle in the bottom of the strainer, thus preventing such frequent clogging of the screen and much of the difficulty experienced in having to clean the screen so often, as in the case when the materials are strained down through the screen and the particles taken out remain on the screen.

Tanks and Agitators. Most of the tanks in use on the stationary spray systems in West Virginia are wooden tanks taken from old portable sprayers and adapted to use in the stationary system. These are cypress tanks of 200-gallon capacity, except in one case where two such tanks have been placed end to end thus making a tank of 400-gallon capacity. These tanks are all equipped with mechanical agitators driven from the pump or the engine.

On one system a rectangular concrete tank is in use. This tank is also equipped with a mechanical agitator. In building a tank of this type, it is important that the corners be filled in and rounded out with concrete. Otherwise, spray materials will settle and collect in the corners.

One owner calls attention to the fact that the elevation of the mixing tank above the pump has a direct bearing on the pressure when the supply in the tank is low. He says: "The bottom of the supply tank should be above the level of the top of the pistons. This will make a difference of 25 pounds of pressure on the line at the same speed of the pump and with the same discharge."

In this connection it might prove valuable to determine the most satisfactory and efficient size for mixing tanks.

Housing. The housing of the plant need not prove an expensive item. The essential features are that it provide ample protection for the working parts, and that it be preferably a two-story structure for ease in mixing and handling materials. Just how far one cares to go in the construction of a building after providing the essential features, depends largely on personal preference.

The Pipe Line. The pipe line is a very important part of the stationary system and experience has taught the West Virginia owners much in regard to the details effecting the efficiency of the line, which to the uninitiated might seem relatively unimportant.

In every case, in systems now operating in the state, black iron pipe is used. The chief reason for its use is its cheapness. No galvanized pipe was found in use in the lines, since owners felt that the pipe rusts out largely from the inside and the benefits to be derived from using galvanized pipe did not warrant the additional expense.

One owner is gradually replacing his pipe as it becomes necessary with copper bearing iron pipe which is now obtainable at slightly higher cost than black iron. This pipe contains a percentage of copper which tends to reduce the rate of corrosion. On the one system where it has been tried it is felt that this pipe is worth the slight additional expense, and is a more economical pipe investment in the long run than ordinary black iron pipe.

On another system in the state practically all of the pipe in use has been purchased second hand. This system was installed in 1921 and some of the pipe has been in use since that time, and still shows little sign of serious deterioration. The fact that satisfactory service may be obtained from used pipe opens up another possibility for reducing installation costs.

For the main lines on the systems studied, the following sizes of pipes were in use: 1, 1¼, 1½ and 2-inch. The two-inch mains were in use on a system where the spray liquid was pumped up hill a total elevation of 400 feet. The large main was used in this case to reduce loss in pressure due to friction.

For laterals, all users of the hydrant systems visited recommend ¾-inch pipe. There are in use for laterals at present, however, pipes of ⅜, ½, and ¾-inch in size. It should be said in defense of the owners who have used pipes as small as ⅜ inch that at the time their systems were installed there was little information on stationary spray plants available to assist them. The ⅜ and ½-inch

sizes are slowly being replaced with ¾-inch pipe, although many laterals of these smaller sizes are still in use. Briefly summed up, the opinion of owners of hydrant systems is that for laterals 1-inch pipe is too large and too expensive, while ½-inch pipe is too small to give the best results, and that ¾-inch pipe should be used.

Due to the topography and irregular layout of orchards in West Virginia, the location and distribution of main lines and laterals is largely an individual problem. In general, the laterals are run off the main line about every fourteen tree rows. With the systems now in use, however, this varies from four to twenty rows. The mains are run in such a way that the orchard may be most easily covered by the system.

Laying the Pipe Line. All pipe lines for hydrant spraying work in West Virginia are laid above ground. This hinders cultivation to some extent, and broken pipes are apt to result occasionally, but this method is preferred to laying the pipe underground since it is cheaper, repairs can be made quickly and easily, and the lines may be laid down or taken up readily. It would seem that there might be decided advantages in running the lines through the trees.

In laying the pipe line it is not necessary that the joints be turned up tightly since the spray materials seal the joints sufficiently. The threads on the pipe should not be leaded in making the connections. One method used in attaching the laterals to the main lines seems to possess merit. For example, if attaching a lateral to a 1½-inch main, a 1½-inch four-way tee is used, this is bushed down to ¾ inch, then a ¾-inch valve is installed, and finally the lateral pipe. This method of taking off the lateral cuts down the friction where the lateral is attached at right angles to the main line. Laterals are taken off the main line usually about every fourteen to twenty tree rows.

There should be plenty of unions in the pipe line to facilitate repair, and taking up or putting down the lines. Ground unions should always be used in this work, thus eliminating the necessity of replacing gaskets frequently.

There should be at least one stand pipe or air chamber in the line, preferably somewhat near the pump. The common type of stand pipe now in use on the systems in West Virginia is a piece of six-inch casing about six feet long, threaded and capped at both ends, with fittings inserted in the cap at one end for attaching the stand pipe to the line, and a pressure gage inserted in the top cap. The principle of the air chamber is readily understood, and its value on a long pipe line under high pressure is easily appreciated. In one case, where the line was exceptionally long, two stand pipes or air chambers were in use.

More difficulties seem to have arisen in connection with the valves than with any other part of the pipe line. The owners of the hydrant systems were unanimous in their opinions that gate valves were not satisfactory for hydrant spraying work, although many gate valves are still in use. Some men had purchased a few high-pressure valves but found this to be an unnecessary expense. One grower has found a shut-off for use in the lines which has proven very satisfactory under test. Another operator has been using a rather more expensive type of globe valve with removable seat, which may be replaced when worn. All owners of systems are still experimenting from time to time with various types of valves in an effort to find the best type for hydrant spraying work. Globe valves and special shut-offs have given the best results thus far.

One difficulty seems to be a tendency on the part of the spray crews to close the valves too tightly. The inevitable result, eventually, is a leaky valve. The valves tend to become corroded and must be cleaned when the spraying season is over. Where pipe lines are taken up, one method of handling is to loosen the valves from the seat and drop all of the valves into a barrel of oil. Used crankcase oil may be utilized in this manner.

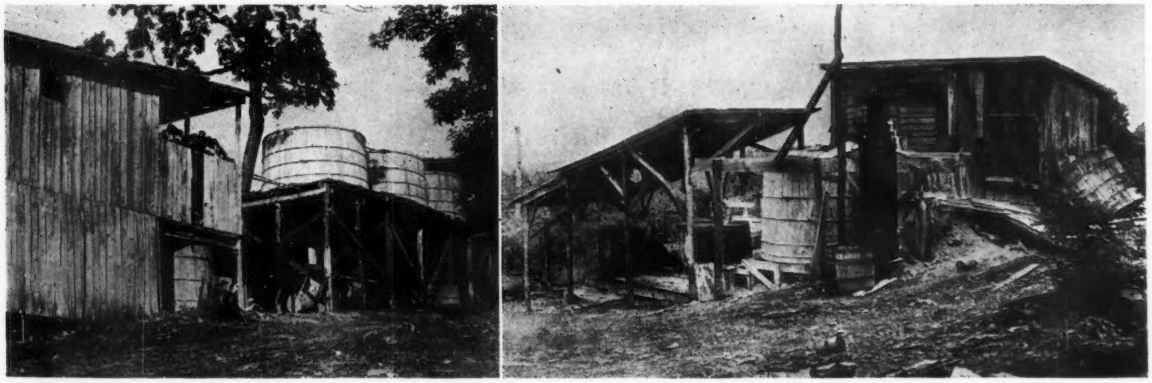
Care of Pipe Line. The usual method followed with the hydrant spraying system is to flush it out with clear water about fifteen minutes before quitting time. When the hose men see clear liquid coming out of the guns they know it is time to quit. The pipe line, thus flushed out, it left full of clear water until the next day or the next spray.

The one owner who did not follow this practice asserted that he never had difficulty as a result of leaving his lines full of spray liquid. When the men started spraying the next time, they merely directed all of the old black spray onto the ground and as soon as the spray cleared up began spraying the trees. The belief that the directing of some of the old spray onto the trees, as is possible with this method, would injure the trees does not seem to have been borne out in this particular instance, according to the owner.

In cold weather the valves should be raised a little. If there is real danger of freezing the lines are drained. To do this, there should be a drain plug at all low points in the line.

Different methods seem to be employed in handling the pipe lines during the winter. The more common is to take up all laterals, after the system has been flushed out with clear water, and store the pipe away over the winter. The valves are cared for as has been described, and the pipe is usually piled away neatly under shelter. One owner, before storing his pipe, drops it in a long trough filled with used crankcase oil. The pipe is then removed, placed on end to drain, and finally stored under cover.

One grower takes up no pipe at all. His theory is that the threads are the weakest part of the pipe, and they are



(Left) This picture shows the central plant housing the working parts of a stationary spraying system on a large West Virginia orchard. The tanks shown are for reserve water storage. This insures against delays due to failure of the main water supply.
(Right) Elaborate housing is not essential to successful operation of stationary spraying plants

merely worn out taking up and putting down the pipe. Of course, there is the labor involved also. In handling his system for winter idleness the valves are lifted off the seats and oil is squirted in the valve after the whole system has been thoroughly washed out with clear water and drained. The threads at all joints are painted as the pipe lies on the ground, as this is the point where the owner feels corrosion will take place most rapidly. All pipe lines are then left down until ready to spray the next year. Occasionally there is a broken pipe due to cultivation or travel over it, but its replacement is not difficult or particularly expensive. Some of the pipe handled in this way has been in use for eight years and shows little sign of serious deterioration.

All owners leave all main lines down all winter. One orchardist painted all main lines with red lead. The painting was for preservation, and the red was used instead of black so that the lines could be readily seen by those operating cultivating equipment.

Hose and Hose Connections. In all cases but one the growers visited were using 250-foot lengths of hose with each spray crew, and on a few occasions were using 300 feet or more. The size of hose in use was ⅜ and ½-inch high pressure hose. The length of life of the hose, from the experience of the West Virginia orchardists, is two years. There is a possibility of getting some service out of it the third season.

For repairs and connections the hose man in nearly every case simply carried a pair of pliers, some soft wire, and hose repair connections. Occasionally a nine-inch pipe wrench was added to this equipment. Patent hose connections and couplings were largely discarded because of troubles and delays caused by them. The hose in use cost from 11 to 21 cents per foot, depending upon the number of plys. No hose reels were used in handling the hose.

As a general rule, there was very little hose trouble. In only one instance was the trouble reported of a serious nature and that was due to the fact that the owner got hold of a lot particularly poor quality hose.

Spray Guns. The spray gun is in general use in the hydrant spraying systems studied in West Virginia. There seems to be a general feeling that there is room for considerable improvement in spray guns for use with these systems. All expressed an opinion that a more satisfactory gun for hydrant spraying conditions than is now available should be developed. The guns in use on the stationary spraying systems in West Virginia are the Boyce, Friend "Pilot," Friend "Hi-Lo," Bean "Pilot," and the Hardy. The Bean seems to be particularly good under windy conditions. The Boyce is used on young trees and also for summer sprays. The Hardy seems to be preferred in applying the dormant spray in some cases, and the Friend guns are used in general spraying throughout the season. Where other types are also in use, the Friend is used on the older trees.

A comprehensive study of spray guns and rods under hydrant spraying conditions, with the view to developing more efficient equipment for use with the system, is recommended by the owners of hydrant spraying systems in West Virginia.

Organization of Crew and Methods of Applying Spray. In every case but one the owners of hydrant spray systems in West Virginia are using three men in each spray crew, two hose men and one man with the gun. Using 250-foot lengths of hose as they do, there seems to be difficulty in cutting down the size of the crew. One man, however, uses a scheme with which two men can handle the work instead of three.

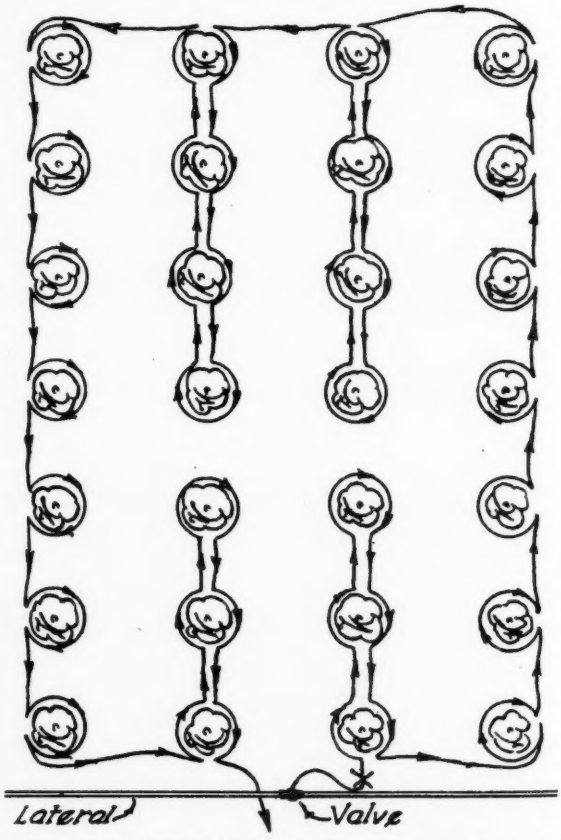
In most cases one man at the central station keeps the machinery running and mixes the materials. One orchardist says he finds it economical to keep one man walking the pipe line while spraying work is on whose duty it is to stop leaks and keep the lines in operating order at all times, thus preventing costly delays.

It would seem that a logical development is toward a scheme where one man comprises the spray crew instead of three as at present. This is already being tried in an orchard nearby in a neighboring state and apparently with success. There one man handles 150 feet of hose and does the spraying himself. In cutting the spraying costs this development seems inevitable. It seems probable that one man with perhaps more frequent set-ups and shorter length of hose will soon replace the three-man scheme now in use.

The more general arrangement of spacing the laterals and faucets is so that a block of fifty-six trees can be sprayed from one faucet. The orchardists visited reported that each spray crew sprayed an average of about four hundred trees per day. Most owners of the hydrant systems have the same crews spray the same blocks of trees throughout the season. In this way they can check on those who are doing careful work, and fix responsibility for careless work without question.

In spraying all followed the practice of having the man with the gun get right under the tree next to the trunk and spray around on the inside, gradually working toward the top until the spray came out at the top of the tree. The man then stepped out and walked around the tree, spraying it completely on the outside. Also, the crew was spraying about 90 per cent of the time, and consequently they could spray more rapidly than crews with portable rigs, since in the latter case two-thirds of the time is spent in travel, refilling, etc.

Some definite scheme for spraying the trees should be followed, in fact, some system is essential if no trees are to be missed. In the accompanying diagram is shown the scheme followed by the grower who uses only two men in his spray crew. From the diagram it can be seen that the hose man does not have to drag more than four tree rows length of hose at any one time.



This diagram shows the path the man takes with the spray gun. The same operation is repeated on the opposite side of the lateral

The Direct Application of Mechanical Power to Soil Tillage[1]

By J. Brownlee Davidson[2] and Edgar V. Collins[3]

IN A PAPER published in the 1914 Transactions[4] of the Society, Mr. Max Patitz quoted an agricultural writer, Chandos Wren Hoskyns, who in about 1850 wrote the following: "But I hold it to be an idea fundamentally erroneous to attempt to combine steam machinery with the plough, and record my conviction that until the idea of the plough, and in a word all draught-cultivation is utterly abandoned, no effective progress will be made in the application of steam to the tilling of the earth." The easiest and most efficient way to utilize the energy of a draft animal for field work is to arrange an implement which the animal may drag. Animal power is essentially linear power. On the other hand, mechanical power is just as easily recognized as rotary power. To change the motion of application of animal power from linear to rotary, or the motion of mechanical power from rotary to linear, results in a serious loss. This situation has been so generally recognized that agricultural history, since the introduction of mechanical power, records many a dream and many an attempt to apply power directly and through a rotary motion.

In this paper an attempt will be made to analyze the distribution of mechanical power in its application to tillage with special reference to the losses incurred and to review the various attempts which have been made to devise direct-driven tillage machines. A study of the subject reveals that a large amount of thought and effort has been devoted to the problem and the patent office is full of inventions which were intended to furnish a solution. Even a cursory investigation of the great amount of study and work which have been given to the problem of applying mechanical power direct to soil tillage must lead to the conclusion that it is not a problem easily solved.

The conventional tractor of the wheel type at the present time delivers the power of the engine through a clutch to a transmission consisting usually of three speed reductions by means of gears or chain belts and sprockets. For each brake horsepower of the engine, the tractor will weigh from 125 to 290 pounds, of which, when at rest, approximately one-third will be on the steering wheels and two-thirds on the drivers. A distribution of the power of the motion under field conditions will be about as follows:

Transmission loss	10 to15 per cent
Rolling resistance	20 to 65 per cent
Lug loss	5 to 10 per cent
Grade loss	0 to 50 per cent
Delivered to drawbar	65 to 25 per cent

The foregoing table has been prepared for no other purpose than to furnish a basis for thought. The losses vary widely and combinations of operating conditions are innumerable. The tillage operations usually performed are plowing and working the plowed land into a seedbed. Perhaps an efficiency of about 65 per cent may be expected for favorable plowing and 25 per cent when working freshly plowed soil.

In connection with a consideration of the efficiency of wheel tractors, mention should be made of cable plowing, although the authors are unable to cite power efficiency data. Steam plowing tackle seems to be well established where unusually severe conditions are encountered. The results of some experiments with which the authors were connected indicated that cable plowing may have some meritorious features which are being overlooked. Present day equipment most certainly involves too much labor in its control to ever meet American conditions.

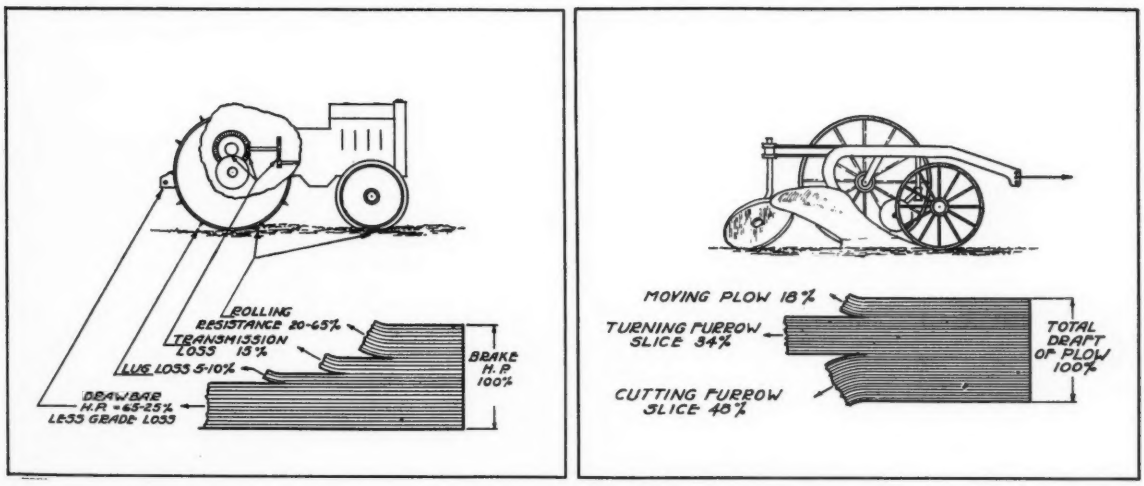
The merits and shortcomings of the modern plow should be mentioned before taking up a discussion of rotary tilling machines. There is much sentiment connected with the modern plow. It is indeed a wonderful implement in its most advanced form. It is simple, of reasonable cost and easily adapted with certain changes to nearly all conditions of soil, and trash and plant growth can be completely covered—an absolute necessity

[1]Paper presented at a meeting of the Power and Machinery Division of the American Society of Agricultural Engineers, at Chicago, December, 1928.

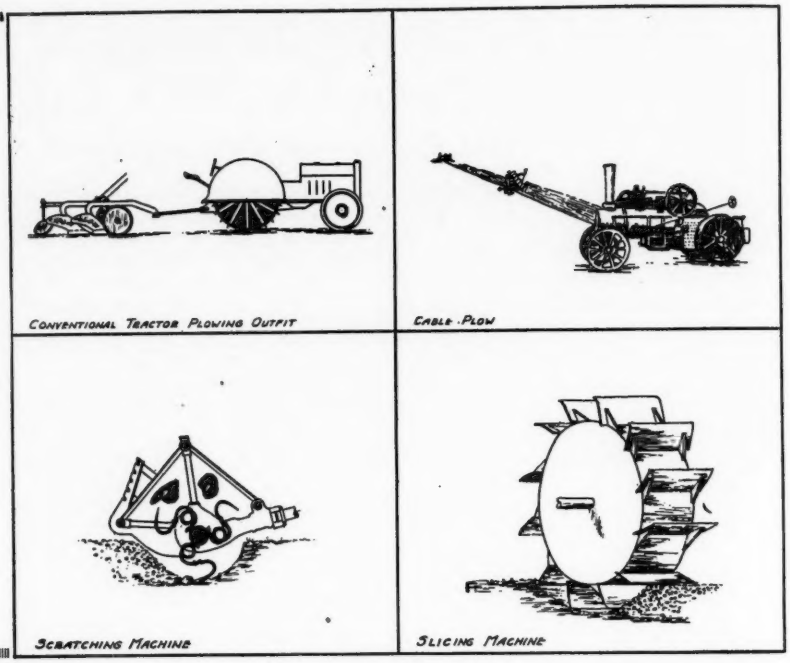
[2]Professor of agricultural engineering and head of the department, Iowa State College.

[3]Agricultural engineer, Iowa Agricultural Experiment Station.

[4]The Rotary Tiller or Soil Milling Machine, Max Patitz, p. 57, Vol. VIII, Trans. A.S.A.E. (1914).



(Left) This diagram shows the distribution, under field conditions, of the horsepower developed by the tractor engine. (Right) This diagram shows the percentages of the power consumed by the plow required to cut the furrow slice, turn it and move the plow



These sketches show the conventional tractor plowing outfit, the cable plow, and two plow substitutes, the scratching machine and the slicing machine

for most conditions. The criticisms which may be made of the plow are:

1. The soil is not pulverized sufficiently well or a complete seedbed is not made which is often desired.
2. The soil is not mixed well.
3. Open air pockets are left below the furrow which are a definite obstacle to the development of the root system of growing plants.
4. The trash and plant growth in the surface is placed in a layer in the bottom of the furrow where it may be an insulator of moisture and is not mixed with soil in such a way as to insure rapid decay.
5. The plow tends to puddle certain soils which after exposure to the sun are left in a hard, cloddy, or baked condition.
6. In certain soils the moldboard plow will not scour if an attempt is made to turn a furrow slice.

An analysis of the power consumption of a stubble plow by Mr. Collins would indicate that almost one-half the power is required to cut the furrow slice loose, about one-third is used for turning and pulverizing, and about one-sixth is required to move the plow exclusive of useful work done on the soil. Many factors are involved and the power requirement will vary much with conditions, but it is significant that so much power is required to loosen the furrow slice before any work can be done upon it. The conclusion must be drawn that cutting of the soil should be reduced to the minimum and that a shaving or slicing process is not economical of power in reducing soil. If a series of points could be substituted for a share, the power requirment could be reduced.

In reviewing the various machines offered as plow substitutes, it has been necessary to coin some new terms which may not be particularly appropriate. Accurate data concerning these various machines are, in many cases, lacking. This is especially true of power consumption.

Scratching Machine. The scratching type of tilling machine is one that has been developed to a greater degree than many others. The machine consists of a self-propelled tractor having a cylinder mounted in the rear and carrying on its periphery a large number of sharp, pointed, hook-like tools. The cylinder is driven with a circumferential speed greater than the forward motion of the machine. The pulverization of soil by driving sharp points into it is no doubt sound in principle and makes for economy of power. Provision is made for the hooks to recede if hard objects like stones are encountered.

The scratching machine as made is a special machine, not particularly convenient to use for other purposes than tilling. Its greatest shortcoming is clearly that trash and plant growth are not covered, and under certain conditions of soil and plant growth the tiller cylinder will clog and become a solid cylinder.

Rotary Hoe Tiller. The rotary hoe type of tilling machine is quite similar to the scratching machine except the cylinder is made up of arms which have hoes or knives at the ends. Inasmuch as these hoes are virtually points, the power consumption ought to be reasonable. Like the scratching machine, this type of tiller does not cover and would not be adapted to general conditions.

Slicing Machine. The slicing or shaving machine type of rotary tiller consists of a number of shares mounted on a drum which is driven over the surface of the soil in a manner much like a milling cutter over a machine part, except in the opposite direction. The mere fact that soil is not easily reduced by a shaving process as indicated by the power used by the share and coulter of a plow would seem to indicate that this type of machine could not by any chance be economical of power. Furthermore, this machine will not cover better than the machines which have been described. The only merit which can be ascribed is that of better pulverization.

Spading Machine. The spading type of tilling machine has not, to the knowledge of the authors, gotten far beyond the experimental stage. In this machine, spading forks are driven into the soil, by an oscillating motion, simulating in a way the manual action of a spading fork. This machine will necessarily be complicated, a special machine, one which will not cover trash well and subject to clogging if cleaning mechanism is not provided. The economy of power is a matter of speculation.

Rolling Fork Machine. The rolling fork type of tilling machine consists of a weighted drum with fork teeth

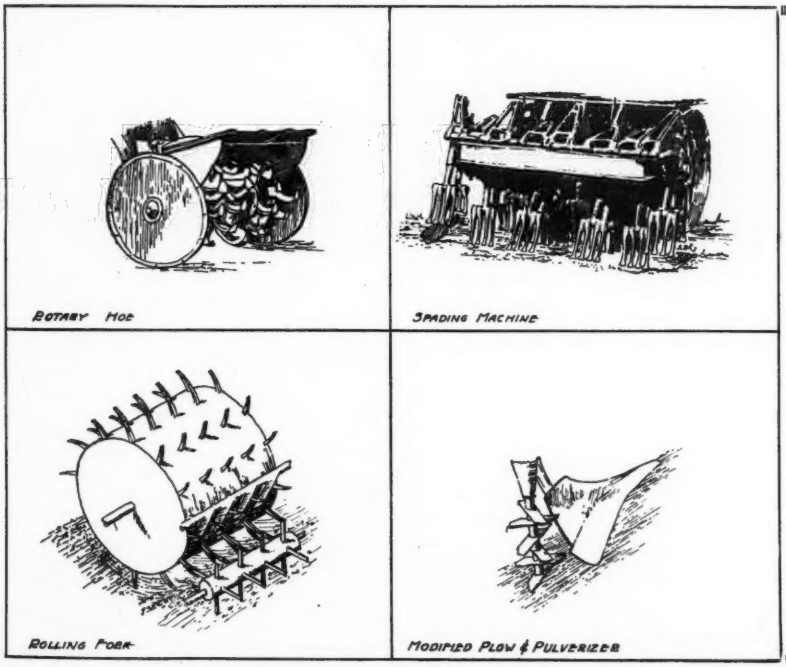
This field near Toledo, Ohio, was covered with a three-year-old alfalfa sod. The modified plow and pulverizer shown was the only implement used to make the seedbed. Note the unusual degree of pulverization of the soil obtained and the complete covering of trash and plant growth

having an involute curvature extending out from the surface a distance equal to the desired depth of tilling. In operation the drum is rolled forward in the direction which will permit the forks to enter smoothly into the soil, but which will lift a layer of soil of a thickness equal to the length of the forks. Scrapers are provided to pry the layer of soil loose and at the same time a beater is used to pulverize the soil. It is the writer's judgment that this machine in its preliminary form was particularly efficient in the use of power. It was in trying to make forks which would not be damaged that the machine was found impracticable. Of course, the machine is very special and did not cover trash.

Modified Plow and Pulverizer. The modified plow and pulverizer represents in its conception the advantage of the plow for covering and the efficiency of the rotary pulverizer driven by power directly by the engine through the power take-off. In this machine a share and shin section of the moldboard are used to turn a furrow slice partially over so that a revolving cylinder of pulverizer blades may act upon the slice from the rear, insuring the same trash and plant growth coverage of the plow. The more recent inventive effort applied to the machine of this type seems to lie more particularly in the relationship and functions of the essential parts.

The pulverizer blades acting upon the loosened furrow slice may be made to produce a very high degree of pulverization for the power used. The time of performing the operation is advantageous and the method is effective. A beating action is economical in that the reduction of particularly hard sections of soil beyond the range of economical reduction does not absorb an excessive amount of power.

A power consumption study of this type of machine is



These four sketches illustrate four different types of machines that have been developed as substitutes for the plow, namely, the rotary hoe, the spading machine, the rolling fork, and the modified plow and pulverizer

interesting. The power requirement of the pulverizer unit can be adjusted by design as to location and speed to use almost any amount of power from a minimum, say, of one-half horsepower per unit as has been actually recorded in test. With a power consumption of 2 horsepower per unit, a high degree of pulverization can be accomplished with good soil conditions and the open pockets in the soil well closed.

The removal of that portion of the moldboard which turns and pulverizes the soil provides a considerable saving in drawbar horsepower required. The average power reduction as revealed by a series of tests in corn stubble and oat stubble, was 14.8 and 14 per cent, respectively, or a reduction from 10.72 to 9.11 drawbar horsepower and from 11.54 to 10.05 drawbar horsepower.

When properly set the pulverizer reaction tends to reduce the drawbar horsepower; in a rather long series of tests, with an accepted adjustment, this amounted to an average of a little more than 4 per cent. These reductions of drawbar horsepower go a long way toward compensating for the power used by the pulverizer. It can be assumed, fairly we believe, that the efficiency in the first instance of the engine power used will be fifty per cent, and eighty per cent in the latter. Thus it is seen that a machine of this type can be operated with a rather small increase of power, say ten per cent. The performance of the combined plow and pulverizer with proper adjustment and power consumption should be equal to plowing with several secondary tillage operations such as one preliminary disking, two subsequent diskings, and one harrowing, and the machine may usually be operated out of the reserve power of the modern tractor engine.

If it is desired to do a very thorough job of pulverizing or beating the soil vigorously for some such purpose as pulverizing sod or the killing of grubs, the width cultivated would necessarily be reduced.

To fully secure all of the benefits of this method of applying power, tractors with less weight per drawbar horsepower will be needed. This will make for increased efficiency. It is significant that several tractors are being designed with this in view.

The World Competition in Wheat Production[1]

By M. L. Wilson[2]

MY SUBJECT may carry with it the idea that the world-wide competition in the production of wheat is to come some time in the future. Actually it is here. Canada in 20 years has jumped its wheat production from 112,000,000 to 500,000,000 bushels. Tremendous docks, terminal elevators and transportation facilities are being rushed to completion on the west coast of Hudson Bay to provide more economical facilities for getting wheat to the Old World. The Argentine has wonderful seaboard shipping facilities which are rapidly being modernized. That country exported 140,000,000 bushels of wheat in 1927 and there is room for much expansion. Russia is now buying machinery and making plans for adding 5,000,000 acres to its wheat acreage in the next three years. Australia has developed a basis, and has doubled its acreage in the last few years. In the United States there are large areas where wheat is a link in the crop rotation system and farms there will continue growing wheat for many years. The struggle is on. The effects already are being felt. The Montana wheat grower is in it and he cannot escape it. His future depends entirely upon how he meets the competition.

This must not be construed as a plea for more and greater machinery, for bigger farms, for factory farming methods, for an industrialized rural life. It is merely a statement of conditions and a hint at what may be expected in the future. Montana can produce high quality wheat at low cost. Farmers here may meet competition only by taking the fullest possible advantage of these possibilities.

To realize what is going on in the world in wheat production it is but necessary to point out that in 1927 there were 58,000 tractors exported from this country and in 1928 the number increased to 64,000. Undoubtedly most of them went into farming areas, particularly into regions of limited rainfall where wheat is an important crop. Combine harvester exports tell the same story. There were 4,707 of these machines exported in 1926; 4,072 in 1927, and 7,317 in 1928. Prospects for 1929 indicate increased exports.

There is but one conclusion to be drawn and that is that other countries are going after the wheat business. How much of the business will be left in the United States will depend largely upon the progress made in reducing production costs. It would appear that it will be necessary for farmers here to stay about two jumps ahead in the race, for there are certain other factors in which foreign areas have the advantage.

Of course, the Montana wheat grower is concerned with developments in other parts of this country as well as in other parts of the world. The fact that so much of the wheat of the United States is produced in diversified farming areas has special significance. Where wheat is but a unit in farm rotations, but one of many money-making crops, there is not so much reliance upon the returns from wheat. Farmers in such areas are in a favorable position to continue growing wheat, for it fits into their farming systems. This is hard competition for the Montana grower, whose sole income is from his wheat crop.

Nor are the other wheat-growing areas of this country standing still in the race to lower production costs. Everywhere new adapted machinery is coming in. Even on the comparatively smaller farms of Ohio, Indiana and other eastern states, tractors, combine harvesters and other equipment designed particularly for the conditions under which they must operate are coming into use rapidly. In the prairie states where much wheat is produced the same development is much in evidence. Everywhere the low-cost movement is under way.

Montana is in the race. In 1924 a group of successful tractor wheat farms being studied by the Montana Agricultural Experiment Station averaged 598 acres; in in 1925 the average size of these farms had increased to 670 acres; in 1926 the average was 812 acres; in 1927 when large-scale wheat farming gained its full impetus, it jumped to 998 and in 1928 to 1,265 acres. According to present plans the group of farms which averaged 1,045 acres in 1924, will average more than 1,800 acres in 1929. The figures refer to land in crop and summer fallow.

This means that the farmers are increasing their wheat-producing facilities per man, largely through the use of larger power units and adapted implements and equipment. The cost of wheat per acre, per bushel and per man is coming down. Where wheat was formerly produced at a cost of 10 to 12 man-hours per acre it is now being produced at less than 2½ man-hours per acre on some farms in the state.

Undoubtedly new methods and new equipment will be developed in the future, even at a faster rate than in the past. If the competition is to be met the producer must be on the alert for the new. It is a silent economic struggle; the efficient will survive; the inefficient will be forced out of the race.

[1]Abstract of an address to Montana farmers during the 1929 Farm and Home Week at the Montana State College.

[2]Professor of agricultural economics, and head of the department, Montana State College.

Method of Calculating Number and Size of Tractors Required for Given Conditions

By L. N. Aginsky[1]

Adapted for AGRICULTURAL ENGINEERING by E. G. McKibben[2]

THE choice of a single tractor powerful enough (if such a machine is available) to do all the work on a certain farm under given conditions is not such a difficult task. In the end it amounts to choosing the proper implements to use with it.

But in using a number of tractors on a large farm it is desirable, if not necessary, to work out a method of calculation which enables one to consider the variety of farm operations during all seasons, and to determine the power required without a preliminary choice of the numbers and sizes of tractors and implements. This is largely due to the fact that the capacity of a given implement varies when being pulled by different tractors on account of various rates of travel.

There are certain correlations between the area of a given farm, the necessary operations in a given crop production program, and the power required to satisfactorily perform these operations. These correlations must include the influence of crop rotation, implements available, soil, weather and other local conditions, skill of operators, ability of manager, etc.

In this paper the author has worked out these correlations mathematically, in the form of clearly stated and rather convenient and easily applied equations, and has suggested a method of procedure in the application of these equations to the problem being considered. It is evident that, in order to make a successful application of these principles, it is necessary to have a rather complete knowledge of the local farming conditions, and of the power and machinery units available. In other words, the use of this method in no way minimizes the importance of the manager's individual ability. It should, however, make the results of his theoretical training and practical experience more effective.

Notation. Following is a list of symbols used in the equations with the factors they represent:

- A = Area in acres
- α = Coefficient representing the portion of the available operating time, during which the implement or tractor is actually operated
- β = Coefficient representing the portion of the normal power actually used in performing a given operation or operating a given machine
- D = Draft in pounds per foot of implement width
- f = Width of implement in feet
- P_b = Normal belt horsepower of tractor
- P_d = Normal drawbar horsepower of tractor
- S = Speed of tractor in miles per hour
- t = Time in hours
- Θ = Ratio of normal drawbar horsepower of tractor to normal belt horsepower
- W_b = Belt horsepower-hours of work
- W_d = Drawbar horsepower-hours of work

Area Performance of an Implement. The following equation gives the area performance of an implement:

$$A = \frac{5280\,\alpha\,Sft}{43560} = 0.121\,\alpha\,Sft \quad \ldots\ldots\ldots\ldots 1$$

where A is the area in acres which can be worked in t hours by an implement f feet in width, which is operated at a speed of S miles per hour α portion of the time.

From Equation 1 it is possible to develop a convenient method of estimating the approximate performance of any given implement. Substituting 10 for t and 0.826 for α

$$A = (0.121)\ (10)\ (0.826)Sf = Sf \quad \ldots\ldots\ldots\ldots 1'$$

Thus, if it is assumed that the implement is actually operated 0.826 of the available time (a reasonable assumption for many implements), its performance in acres for a ten-hour day will be equal to the product of its operating speed in miles per hour times its width in feet.

Implement Requirement of an Area. Solving Equation 1 for f

$$f = \frac{A}{0.121\,\alpha\,St} = \frac{8.26A}{\alpha\,St} \quad \ldots\ldots\ldots\ldots 2$$

where f is the width in feet of an implement required to work an area of A acres in t hours, when operated at a speed of S miles per hour α portion of the time.

Power Requirement of an Implement. The following equation gives the power requirement of an implement:

$$P_d = \frac{5280DfS}{(33000)(60)\beta} = \frac{0.00267DfS}{\beta} \quad \ldots\ldots\ldots\ldots 3$$

where P_d is the drawbar horsepower required to operate an implement f feet wide, which has a draft of D pounds per foot of width, when it is operated at a speed of S miles per hour, and only β portion of the power is utilized.

Implement Performance of a Tractor. Solving Equation 3 for f,

$$f = \frac{P_d\beta}{0.00267DS} = \frac{374.5P_d\beta}{DS} \quad \ldots\ldots\ldots\ldots 4$$

where f is the width of implement in feet which a tractor using β portion of its drawbar horsepower will operate at a speed of S miles per hour against a draft of D pounds per foot of width.

Area Performance of a Tractor. The following equation gives the area performance of a tractor:

$$A = \frac{(33000)(60)P_d\,\alpha\,\beta t}{43560D} = \frac{45.45P_d\,\alpha\,\beta t}{D} \quad \ldots\ldots\ldots\ldots 5$$

where A is the area in acres which a tractor using β portion of its drawbar horsepower, P_d, α portion of the time, will work in t hours, while pulling an implement with a draft of D pounds per foot of width.

Power Requirement of an Area. Solving Equation 5 for P_d

$$P_d = \frac{A\ D}{45.45\,\alpha\,\beta t} = \frac{0.022AD}{\alpha\,\beta\,t} \quad \ldots\ldots\ldots\ldots 6$$

where P_d is the drawbar power required to work a farm of A acres in area in t hours, using β portion of its power α portion of the time, and operating an implement with a draft of D pounds per foot of width.

Work Requirement of an Area and an Implement. Multiplying both sides of Equation 6 by t,

$$W_d = P_d\,t = \frac{0.022DA}{\alpha\,\beta} \quad \ldots\ldots\ldots\ldots 7$$

where W_d is the work in available drawbar horsepower-hours required to work an area of A acres with an implement which has a draft of D pounds per foot of width.

Equations for Unit Performance and Requirements. Any one of Equations 1 to 7 may be reduced to the unit basis for any factor considered in the equation by substituting unity for the proper symbol. Thus it is possible to convert each of the equations given into a series of equations, each of slightly different form, and which under certain conditions may be more convenient to use

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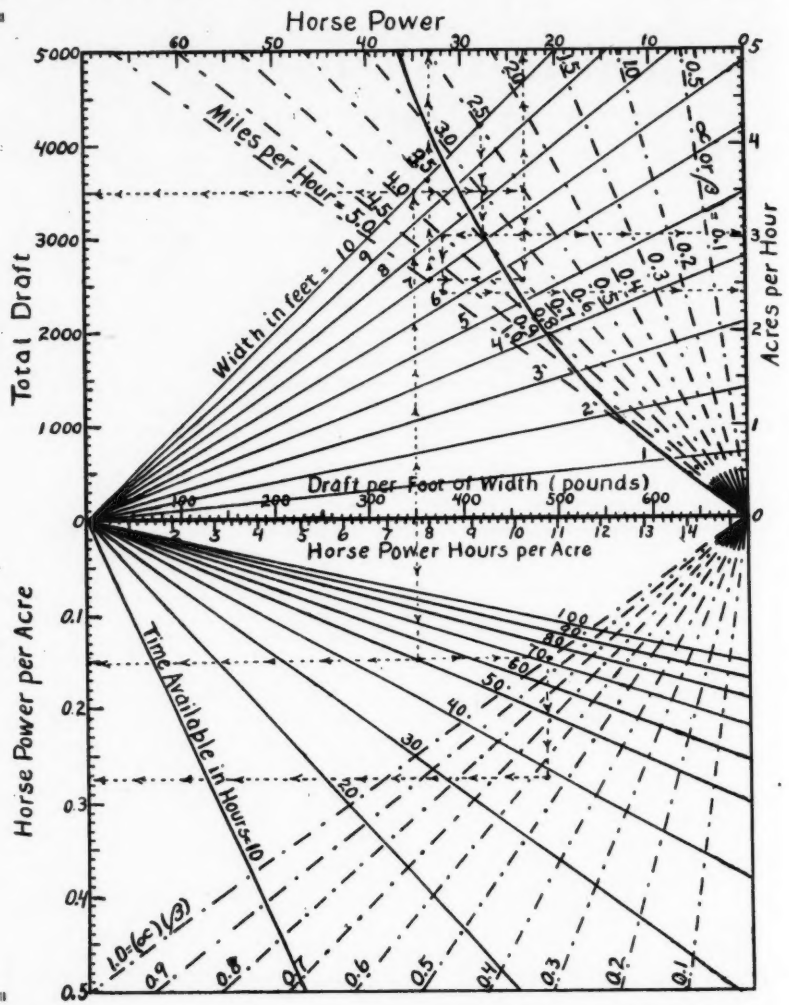


Explanation of the Chart

Values for the various factors in the equations are represented by numerical scales in the chart, including the four sets of radial lines and the upper part of the horizontal center scale. Values for which these factors are solved automatically by the chart are represented by the scales on the border of the chart and the lower part of the horizontal center scale. The light broken lines with arrows illustrate the procedure in using the diagram under one particular hypothetical set of conditions, as referred to in the text.

than the more general form which is given. Since this procedure can be easily handled by any engineer who is competent to use the type of analysis being considered, it seems unnecessary to include these additional equations. Also their exclusion simplifies the text, particularly the symbolism required, and increases the readability of the article.

Belt Horsepower. If Θ is the ratio of drawbar horsepower to belt horsepower, $P_d = \Theta P_b$. Therefore, all the equations having to do with drawbar horsepower, or containing P_d, may be converted to belt horsepower conditions by substituting ΘP_b for P_d.

Metric System. The above equations may be changed to the metric system expressing width of implement in centimeters, speed in kilometers per hour, area in hectares, draft in kilograms, power in metric horsepower, and work in metric horsepower-hours by substituting as follows:

0.001	for	0.121	in Equation 1
1000.0	for	8.26	in Equation 2
0.0037	for	0.00267	in Equation 3
270.0	for	374.5	in Equation 4
0.27	for	45.45	in Equation 5
3.7	for	0.022	in Equation 6
3.7	for	0.022	in Equation 7

Graphical Representation. The foregoing equations may be conveniently shown and used as curves, or these curves may be combined into charts of various forms similar to that shown in the accompanying graph. The most desirable form of these charts and and the magnitude of the scales used will of course depend upon the individuality of the engineer using them and the conditions under which they are to be used.

The use of the chart shown can probably be best explained by considering an actual problem. Therefore, let us assume the following given information: Draft per foot of width, 350 pounds; width of implement, 10 feet; speed of tractor, 2.5 miles per hour; time available, 50 hours; portion of normal drawbar power used, 0.7; portion of available time used in actual operation, 0.8.

Locate 350 on the "draft per foot of width" scale in the center of the chart, and following the vertical line to the line representing a 10-foot width, then follow the horizontal line to the left to the total draft scale. The total draft may then be read as 3500 pounds.

From the point where the vertical line representing a 350-pound draft per foot strikes the line representing a 10-foot width, follow the horizontal to the line representing 2.5 miles per hour; then follow the vertical line to the horsepower scale where the horsepower required for this combination of draft, width and speed is read as 23.3. In case only 0.7 of the normal drawbar horsepower is to be used, return back down the vertical line to the line representing a value of β of 0.7; then follow the horizontal to the line representing a value of β of 1.0, and follow up the vertical to the horsepower scale; where the drawbar horsepower of the required tractor is read as 33.3.

Start from the point of intersection of the line, rep-

resenting a 10-foot width, with the line representing a speed of 2.5 miles per hour; follow down the vertical to the heavy curved line, and follow the horizontal to the area per hour scale, where the answer is read as 3.025. In case the implement is actually operated only 0.8 of the available time return along the horizontal line to the line representing a value of α of 0.8, then follow the vertical to the line representing a value of α of 1.0 and follow the horizontal to the acres per hour scale; indicating that under these conditions the given implement will work only 2.42 acres per hour.

The horsepower-hours of work per acre corresponding to a draft of 350 pounds per foot of width may be read directly from the lower of the two central scales as 7.7.

The horsepower required per acre to accomplish an operation having a draft of 350 pounds per foot of width in the actual operating time of 50 hours is obtained by following down the vertical from 350 pounds draft to the line representing an available time of 50 hours, then following the horizontal to the horsepower per acre scale where the answer is read as 0.154. In case only 0.7 of the normal drawbar power is to be used, and the implement is to be actually operated only 0.8 of the available time, this power will be 0.7 x 0.8 or 0.56 of the required power. This required power is found by returning along the horizontal line to the line representing a value of $\alpha \times \beta$ of 1.0, then following the vertical to the point representing a value of $\alpha \times \beta$ of 0.56, and following the horizontal to the horsepower per acre scale, where the answer is read as 0.275.

Procedure. To determine the number and size of tractors and implements for a certain farm, the following method is recommended:

1. Choose the crop rotation.
2. Determine the operations it is necessary to perform, and the total area in acres or hectares on which each operation is to be performed.
3. Determine the draft per foot or centimeter of width of each implement which is to be used in field work, and the amount of work in horsepower-hours, for each unit of non-field work.
4. Choose the makes of tractors which for various reasons seem best fitted for the local conditions, and determine normal belt and drawbar horsepower, normal working speeds in miles or kilometers per hour, with corresponding drawbar pulls in pounds or kilograms for each tractor on every operation for which you expect to use it.
5. Using Equation 4 determine for each of the chosen tractors what width of each implement it can pull. It must be kept in mind that these widths have to be in terms of the implements actually available on the market. Determine the total draft of the implement of each kind which you have chosen for each tractor.
6. Determine the coefficient β (that portion of its power which will be used) for each tractor on each operation, by dividing the total draft of the implements it will pull by its normal drawbar pull. Determine the value of β for non-field work by dividing the power required to run a given machine by the normal power of the tractor with which it will be operated. Determine for each type of operation the average value of β.
7. Determine the periods or seasons for each operation and the number of working days available in each period. Choose for each season and operation reasonable working hours per day and determine the total number of hours available for each operation.
8. Determine for each period and operation the coefficient α, indicating the portion of available time spent in useful work.
9. Summarize similar operations which must be performed in the same calendar period or season.
10. Work out a calendar schedule (diagram) of all operations in order to determine overlappings in time.
11. Using Equation 6 determine the power required for accomplishing each operation in the available time.
12. Summarize the power required for the operations which must be done in the same period (overlapping operations).
13. Work out a schedule (diagram) of power required in succeeding periods. The peak load of this schedule or diagram will now indicate the required horsepower of tractors. If the diagram shows high peaks of power, it is desirable to look over all operations in order to choose such as do not absolutely have to be performed within the overloaded periods, and which may be done in earlier or later periods. Such operations may then be transposed to one or the other side of the peak of the diagram. Sometimes when introducing tractors it may be a good plan to make some changes in the crop rotation or in the system of work in order to equalize the tractor load in certain periods and thus reduce the maximum power required. It may be useful to introduce on the farm some new enterprises which could occupy power and labor during the time they are free from other work between the regular farming periods.
14. Choose tractors which will be able to do all the necessary operations as shown in the final power requirement schedule or diagram of Item 13.
15. Choose implements for each tractor using the data of Item 5.
16. Make a new calculation with the tractors and implements selected to be sure that all operations may be accomplished in the available time.

The most important phase of the whole problem is the choice of the proper size of tractor for the local conditions. Up to the present time this question has had no satisfactory solution, and in spite of the most careful and thorough application of a scientific analysis the agricultural engineer in charge will have to depend to a certain extent upon his good judgment.

Large tractors have many advantages over the small ones. They reduce the labor requirement, and in many cases can be better loaded with the implements on the market, etc. But small tractors are sometimes preferred for light work, because in such cases it may be inconvenient to pull implements of sufficient width to give a large tractor an economical load.

It would seem that the best results could be obtained with large and small tractors working together on the same farm, each being used for the operations to which it is best adapted.

Plow Companies Cooperating in Corn Borer Fight

TWELVE leading manufacturers of plows are cooperating with agricultural engineers of the United States Department of Agriculture in an effort to find out what types of plows are most useful for destroying the corn borer by plowing under cornstalks and other refuse. They have loaned plows of more than thirty different kinds and sizes which are being tested in the corn-borer area near Toledo, Ohio.

This group of plows is one of the most interesting ever assembled for test in this country. They range in size from the old style 12-inch horsedrawn walking plow to the newest type of 18-inch gangs pulled by large tractors, and no two mouldboards are quite the same. Some turn low, sharp furrows; others lift the dirt high and drop it in an easy curve, and one has a power-driven beater to pulverize the earth as it is turned. Special attachments designed to bury the stalks more thoroughly have also been furnished by several manufacturers.

An Experiment Station Building Project

By Deane G. Carter[1]

A FARM building project involving an investment of more than $100,000 was carried out by the agricultural engineering department of the University of Arkansas during 1928. The complete project covered the design, construction and equipping of thirty-five buildings on the Arkansas Agricultural Experiment Station farm at Fayetteville and on the farms of three branch stations. These structures ranged from small utility buildings erected at a cost of $125.00 to experimental and residence buildings representing investments up to $10,000.00. Equipment involved included heating, lighting, water supply, sewage disposal, plumbing and experimental machinery.

When opportunity was offered to prepare plans and specifications and to excerise general supervision of the contracts, the work was established as an experiment station project in order that time might be provided to prepare plans, specifications, contracts, analyses of costs and a statement of the purposes and requirements of experiment station or large farm buildings. Plans were in the course of preparation for more than a year. The construction program was approved in May, 1928, by the president and board of trustees of the University of Arkansas and by the director of the station.

Objectives. The purposes or objectives of this project were:

1. To study the requirements of buildings for branch experiment stations
2. To design the necessary buildings on the basis of requirements found
3. To make necessary adaptations to the needs of the cotton, rice, and fruit and truck branch stations
4. To prepare specifications, estimates and contracts, and to obtain and analyze records
5. To develop plans for barns, dwellings and smaller structures having an application also to the commercial farm.

Requirements. Preliminary to a statement of the needs for the farms under consideration, a study was made of the buildings at a number of branch experiment stations. There are approximately 150 branch and main experiment station farms in the United States. Correspondence with about 30 station superintendents indicated that the wide range of location, finance and purpose had prevented the establishment of any fixed policy. Apparently the buildings on institutional farms have been designed separately as needed. Most stations appear to have been handicapped by lack of funds. The median cost on 20 stations was $24,600.00. The median size of experimental farm was 185 acres.

From other detailed statements derived from the study, together with the experience of our experiment station director, the following general requirements for these buildings were set up:

1. Adaptability to the location, use, local materials and climatic conditions
2. Facilities for experimental work
3. Form a complete experimental and administrative unit
4. Provision for accommodation of group meetings, visitors and scientific workers
5. Come within reasonable costs limits
6. Be practical, and serve as models of suitable construction
7. Be reasonably permanent
8. Be unified and harmonious
9. Be built to a permanent plan to avoid additions or makeshift changes
10. Be modern as to facilities, sanitation and experimental equipment.

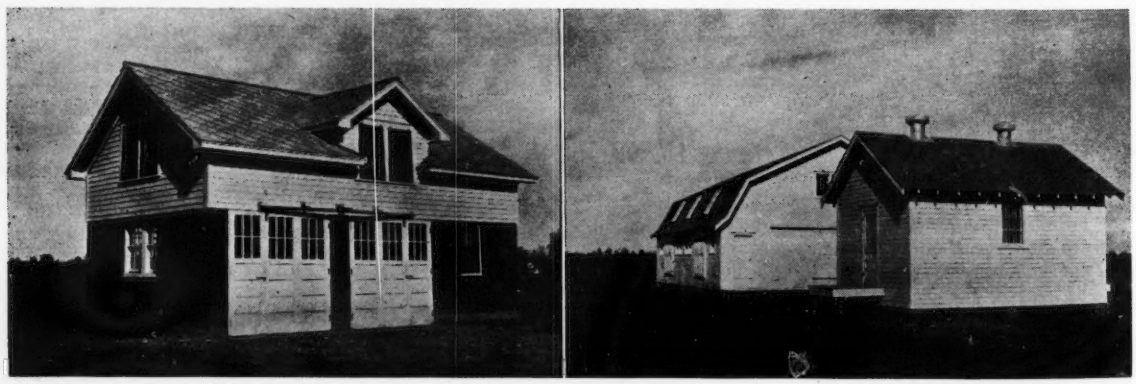
It was decided that to meet these requirements the farmstead plans should allow for future expansion. The buildings so far as possible were to be designed so that wings or extensions might be added in a satisfactory manner. A cost limit of $30,000.00 per station was set for construction, with not over $5,000.00 for all utilities and landscaping.

Each branch station was made a self-contained unit, as far as possible, to include adminstration, laboratory facilities for technical workers, provision for group meetings and visitors, residences for the assistant director in charge, the foreman and laborers. For each type of experimental work the necessary storage and working space was provided.

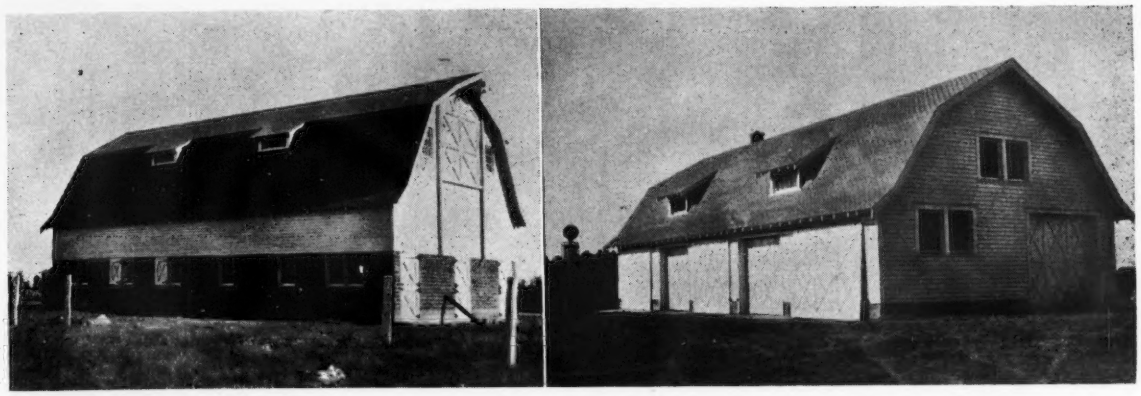
As a result of this study, a complete series of plans was drawn up, all plans being original. A number of the plans are entirely suitable for distribution as representing practical farm construction. Other structures are more particularly for experimental farms or for administration. Cost figures on the entire project are recorded but have not yet been analyzed completely.

The Buildings. In the preparation of complete plans,

[1]Professor of agricultural engineering and head of the department, University of Arkansas. Mem. A.S.A.E.



(Left) Combined two-car garage, utility room and three-room apartment. (Right) Sweet potato curing house and fruit and vegetable building at the Fruit and Truck Branch Station, Hope, Arkansas



(Left) A unit-space barn with tile and frame exterior. (Right) One of the machinery buildings

some experimental ideas were put into effect in practical ways. It was possible in some cases to develop entirely new structures based on the requirements in mind. The following statements afford a summary of the type of plan, construction and building developed in the project.

The man in charge will reside at the station, and it was the intention to provide every facility for adequate housing that might be possible elsewhere. The residences were built at the professional standard of housing, that is, they are six or seven room, two-story residences, with three bedrooms, two baths, sun room, sleeping room, breakfast alcove, and basement. The construction includes concrete basement, frame walls with brick veneer, fireproof roof, hardwood floors and sand-finish plaster walls. There is heat regulation, constant hot water, plumbing and electricity. Each house is wired for power. In style these houses represent conservative adaptations of colonial types. Each of the three is based on an original plan, with construction standards comparable to the best brick exteriors. These houses represent good, modern construction fitted as necessary for rural conditions. The cost range was from $7300.00 to $9500.00.

The foreman's residence is of a somewhat better than average small, frame one-story, four-room type. To us it represents a model of low-cost construction suitable for the farm owner of limited means. There are two bedrooms, kitchen, large living room, bath, dining alcove, clothes closets, built-in kitchen equipment, plumbing and electricity. The walls are plastered, woodwork enameled and floors sanded and finished. The total contract cost was $1900.00.

Homes for workmen and tenants are not usually built with attention to appearance, comfort or durability. In the nine tenant houses constructed in this program these factors were emphasized. While this type of house does not permit of any so-called modern facilities, we provided tile-lined brick flues, solid foundations, composition shingle roof, paint, screens, insulating paper and ceiling. The sizes are two and four-room. When possible we included plain electric lights, and in two houses water closets were installed. Outside water lines run to each house. The construction cost ranged from $600.00 for the two-room houses to $1200.00 and $1400.00 for the four-room houses.

To eliminate small, costly and usually unsightly structures each tenant house is supplemented by a small utility house. This building matches the house in construction. The facilities provided vary, but may include a poultry house space for 25 hens, a ceiled-off space for outdoor toilet, fuel space and storage. The cost of these buildings varied from $125.00 to $175.00.

It was necessary to provide a garage near the main residence for the director's personal car and for the station car. Space was needed for housing the central water supply system, and quarters for tenant and caretaker were necessary. By providing these features in one building it was possible to match roofing, side walls, and construction with that of other buildings at no greater cost than for separate, cheaper, unmatched structures. This building cost about $1450.00 for two car spaces, utility room, and a three-room apartment.

Satisfactory administration of an experiment station, the reception of visitors, the keeping of records, and the conduct of research demand an administrative center separate from residence or outbuildings. The office or administration building was designed to serve these purposes. It was given a prominent location. A reception office and private office was provided, with record room adjacent. Connected to the offices is a laboratory wing fitted for scientific tests and studies. A women's lounge and rest room is provided with a separate outside entrance. At the rear of the building are two bedrooms and bath for visiting technical workers. The full basement has space for a central heating plant, fuel room, storage, and for future laboratory expansion. This building has a brick exterior, asbestos roofing, and is well finished throughout.

Each station is provided with a tile and frame barn, designed to accommodate all feed, hay, work stock and dairy cows. The construction and exterior is identical for all, but each floor plan is individual. These three barns and a new 50-cow dairy barn at the main station were planned on the 40-inch unit system described previously in AGRICULTURAL ENGINEERING[2].

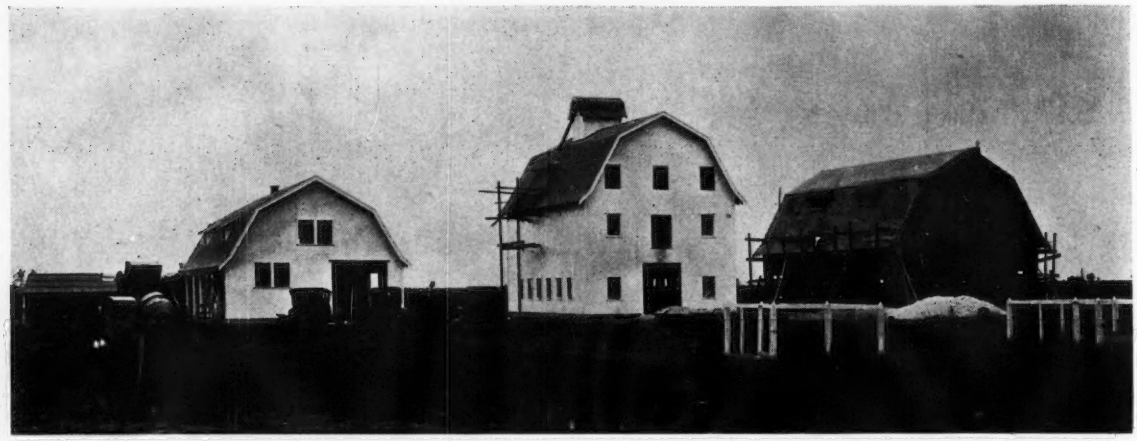
The machinery building has a shop section at one end. Other portions consist of storage units, a drive-through section, and a large machine section, so, by the same plan, any extension of size can be made to meet the needs. The second floor may be all or partially floored; in one instance it serves as an auditorium for group meetings.

The cotton building was evolved from the traditional gin building and adapted for experimental purposes. Storage bins for cotton seed, sack lots and baled cotton are included. A laboratory room and record room is provided and in connection is an enclosed scale house. The second floor is for the ginning machinery and ample space is allowed below for experimental machines.

The rice building is not simply an elevator but is designed for sack and bin storage; seed bins; gravity movement of all grains; and space for cleaners, moisture apparatus and experimental milling equipment.

For the fruit and truck station an insulated sweet potato curing house and a sky-lighted fruit and vegetable grading house were built to meet the requirements and to conform in general style to the other buildings.

[2]The Unit Space Method of Barn Building, by Deane G. Carter, AGRICULTURAL ENGINEERING, Vol. 9, No. 9 (September, 1928), pp. 271-273.



A building group on the rice branch station of the Arkansas Agricultural Experiment Station, at Stuttgart, Arkansas. The rice building is the one in the center

Construction. In the project it is probable that harmony of construction could not have been secured except by the design of the whole farmstead at one time. It is also more economical to erect as many of the buildings as possible at once rather than one at a time. The plans were made to meet the needs of the station for many years ahead. Yet so far as possible they are such that additional structures or extensions may be provided in the future without destroying the appearance of the buildings or the farmstead.

An interesting sidelight on the building program was the large number of commercial products used, and the range of information required from the manufacturers and trade associations. Frequent reference was made to the handbooks and aids supplied by these groups in the handling of details and specifications.

Both insulating paper and commercial insulation was used in residences, in connection with the heating systems, and in the sweet potato storage house. Three complete heating systems were designed with the aid of a manufacturer of heating equipment. One trip was made to visit a maker of cotton ginning machinery. Reference in several cases was made to commercial literature for information on brick construction, concrete, sewage disposal, millwork, built-in equipment and plumbing.

While it is the function of the agricultural engineer to make plans and designs to meet the requirements set up, commercial products must be utilized, and to the best advantage. In this connection it would appear advisable that agricultural engineers, who have a considerable influence on the farm building and equipment program, should be familiar with the recommended methods and the aids supplied both by the manufacturer and the service association.

A partial list of the commercial products used in the building program includes five septic tanks; three heating plants, each serving two buildings; nine complete sets of plumbing; three pressure water supply systems; complete electrical equipment; three makes of barn equipment; hollow tile, brick, concrete, steel and frame construction; three types of roofing; elevating machinery; cotton equipment; and miscellaneous fixtures and materials.

Mysterious Barn Fires Charged to Spontaneous Combustion

MANY of the "mysterious" barn fires occurring throughout the rural communities of the United States along about harvest time are caused by "spontaneous combustion," or "self-ignition," of hay and other agricultural products, according to David J. Price of the United States Department of Agriculture.

Although it was recognized centuries ago that stored hay, manure, and other farm products occasionally become hot enough under certain conditions to ignite, very little attention has been given to the problem until recent years. Even yet there is a dearth of scientific information on spontaneous combustion.

The unusual conditions in the Vermont flooded areas, where the water reached the hay mows of hundreds of barns, offered exceptional opportunities for such studies. A clear-cut case of spontaneous ignition occurred near Middlesex, Vermont, when a barn containing 50 tons of hay burned while standing in three to five feet of water. No heating of the hay had been noticed before the flood, but considerable steaming was in evidence 24 hours after the waters had receded. The flood occurred early on Friday morning, November 4, (1927) and the water rose to cover the hay to a depth of 17 feet. The barn burned between four and five o'clock on Monday afternoon, November 7, or about two days after the waters receded. On Sunday morning much heating had been noticed, and on Monday a distinctly charred odor was observed before the fire started. The urgent need for extensive research upon "spontaneous heating" of farm products was emphasized by lack of scientific knowledge with which to meet the situation in Vermont.

In a three-year period, more than 400 barn fires in the Province of Ontario were investigated and the authorities concluded that "at least one-half of these fires have been directly and solely caused by spontaneous heating." It appears also from these investigations that there are a number of good reasons for the increased number of "mysterious" barn fires. Many of them are closely related to changes in farming. The present crops, now consisting largely of alfalfa and clover hays, can not be properly cured and put in condition to be housed, as was done in former days with crops which consisted principally of timothy. The old-time custom of salting hay in the mow has largely disappeared, an unfortunate situation as salting has been an accepted means of retarding combustion. New types of machinery also may be held responsible for handling the crop so rapidly that it does not have time to cure properly before being stored.

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Requests for copies of publications abstracted should be addressed direct to the publisher.

The Economic Limit of Pumping for Irrigation, W. L. Powers (Oregon Station (Corvallis) Bulletin 235 (1928), pp. 48, figs. 30).—Studies are reported which show that the soils best suited to supplemental irrigation in the Willamette Valley of Oregon are those that are free working. Crops found to give best response to supplemental irrigation in the Valley are the truck crops, crops grown for intensive dairying, and row crops that make their maximum growth late in the season. Potatoes and beans have been found to give large returns from irrigation. Data are given on the available water supply and the types of pumping equipment best adapted for use in the Valley.

Drainage Record and Ground Water Movement (Florida Station (Gainesville) Report 1927, pp. 114-117, fig. 1).—Data on the control of ground water level in Everglades soils are presented and briefly discussed.

The Elements of Hydrology, A. F. Meyer (New York: John Wiley & Sons; London: Chapman & Hall, 1928, 2. ed., rev., pp. XV + 522, figs. 313).—This is the second revised edition of this book. It contains the following chapters: The atmosphere —its temperature, pressure and circulation; water—its various states and their properties; precipitation—its occurrence and distribution; evaporation from water surfaces; evaporation from land areas; transpiration; deep seepage; run-off; stream-flow data; supplementing stream-flow data; modification of stream flow by storage; and note to teachers of hydrology.

Run-Off Water Losses in Relation to Crop Production (Texas Station (College Station) Report 1927, pp. 58, 59, 97, 98).—The progress results of this study indicate that one of the most important factors concerned in the loss of run-off is the rapidity of the fall of water. The physical condition of the land is apparently an important factor in the water loss. There seems to be a considerable difference in the losses from lands under different crops. Results indicate that milo is more efficient in this respect than cotton early in the season, depending probably upon the extent to which the crop is taking water from the soil.

Irrigation of Small Grain, W. W. McLaughlin (U. S. Department of Agriculture, Farmers' Bulletin 1556 (1928), pp. 11 + 14, figs. 5).—This bulletin is a revision of and supersedes Farmers' Bulletin 863.

Pump Irrigation Results, H. E. Weakly and L. L. Zook (Nebraska Station (Lincoln) Bulletin 227 (1928), pp. 12, figs. 3).—This bulletin reports certain results secured by pump irrigation at the North Platte Substation. The chief crops irrigated were corn, potatoes, alfalfa, Sudan grass pasture, and forage sorghum. These crops were grown in fields from 1 or 2 up to 10 acres in size. The work was conducted on 1/10-acre plats. The data are reported in tabular form.

The Development of Water Supplies for Irrigation in Nevada by Pumping from Underground Sources, F. L. Bixby and G. Hardman (Nevada Station (Reno) Bulletin 112 (1928), pp. 38, figs. 16).—This bulletin presents general information concerning the pumping of water from wells for irrigation in southern Nevada. The material is not technical in character, being more a statement of the general principles governing the development of underground water supplies.

The Possibilities of Power Alcohol and Certain Other Fuels in Australia, G. A. Cook (Council of Science and Industrial Research (Melbourne) Bulletin 33 (1927), pp. 106).—This study brings out the fact that, as regards fermentation power alcohol, Australia appears to be in much the same position as most other countries in that the necessary raw materials are in general too valuable as foodstuffs to permit of their use for distillation. It appears, however, that in certain parts of Australia raw materials could be produced at such a cost as would enable any alcohol distilled from them to compete with gasoline, particularly if such alcohol were marketed in the areas of production.

This consideration of the cost of raw materials applies more to cereals than to tubers. In fact, in some Australian localities the fermentation of certain varieties of tubers is commercially attractive. Cassava, Arrowroot, sweet potatoes, and beets are worthy of consideration in this connection. It is thought questionable whether fermentation alcohol can completely solve the national fuel problem.

As regards synthetic methods, it appears that neither the ethylene nor the acetylene processes have much hope of commercial success in Australia.

The Combine, J. G. Taggart (Canada Experimental Farms, Swift Current (Sask.) Station Report Supplement 1927, pp. 18-23, fig. 1).—The results of experiments with the combine during 1927 are briefly reported. It was found that in general the combines worked well in heavy, lodged crops. Crops that were partially destroyed by hail or frost were harvested economically by the combine when otherwise the cost of harvesting and threshing would have amounted to more than the gross return.

In experiments with a heavy crop with a rank growth of straw which was twisted, tangled and lodged, the combine-harvested portion yielded 36.02 bushels per acre and the binder-harvested portion 30.3 bushels. With a crop which was short, thin, and low, due to the ravages of wireworms, it was impossible to harvest cleanly with the combine.

A study of experience with 770 combines in western Canada during 1927 showed that unfavorable weather was the principal factor interfering with the continued operation of the combine.

The most noteworthy development in the use of the combine was the introduction of the swather attachment. The object of this attachment is to eliminate a portion of the waiting period between binder harvesting and combine harvesting. The crop is cut and laid in swaths, each of which contains the straw and heads of a strip from 16 to 24 feet wide. The cutting mechanism may be either the combine knife and a table or one or more headers. Threshing is performed by means of the combine equipped with a special pick-up device.

It was found that a crop containing a quantity of green weeds could be better harvested by the swather than by the straight combine.

Some Power Problems of the Farm, J. M. Smith (Alberta University, (Edmonton) College Agricultural Bulletin 17 (1928), pp. 40, figs. 24).—An outline is given of power problems of the farm, including discussions of horsepower, brake and drawbar horsepower, sizes and speeds of pulleys, and belt lacing.

[Agricultural Engineering Studies at the Arkansas Station], H. T. Barr, B. S. Clayton, and D. G. Carter (Arkansas Station (Fayetteville) Bulletin 231 (1928), pp. 8-10).—Progress data are presented from investigations on plow drafts, dynamometer design, pumping plants for rice irrigation, durability of posts and farm building design.

The results of 500 plow draft tests over a period of two years led to the conclusion that the draft per square inch of furrow section is inversely proportional to the depth of cut and to the width of plow bottom.

In the post experiments it was found that after five years galvanized steel posts showed no injury; black metal posts, painted, showed increased rusting and some pitting below ground. Pressure treated pine posts showed no decay. Butt-treated, unseasoned oak posts apparently were not improved by treatment, as 62 per cent were unfit for use after four years. Cured native oak posts, given a 24-hour butt treatment in hot and cold bath creosote failed 3.1 per cent at five years, 16.8 per cent at six years, and 28.06 per cent at seven years. At the end of two years small treated post specimens showed slight fungus growth and termite action, while untreated checks showed 7.7 per cent complete failure and approximately 33 per cent some decay or termite damage.

In a study of barns and barn plans it was found that a lengthwise unit distance of 40 inches in multiple, or fractional parts met practically every animal and storage need for farm barns. The unit space adopted affords a highly flexible plan arrangement for individual needs.

A comparison of commercial house plans with Arkansas farm homes indicated that the commercial plan meets with needs of rural conditions so far as construction, finish, sanitation, and utilities are concerned, but certain modifications of plans are necessary if the commercial plan is to meet rural needs. Based upon Arkansas conditions, the principal modifications appear to be more emphasis on the one-story house, larger kitchens, fewer and larger rooms, smaller total area, more work-porch area, and direct entrance to the kitchen from the outside.

Tractive Resistance of Automobiles and Coefficients of Friction of Pneumatic Tires, T. R. Agg (Iowa Engineering Experimental Station (Ames) Bulletin 88 (1928), pp. 60, figs. 50).—Studies conducted in cooperation with the U.S.D.A. Bureau of Public Roads are reported. The results indicate that there is no great difference in the tractive resistance of any particular vehicle on various road surfaces that are reasonably smooth and hard. Paved surfaces in good repair do not give as wide a range of variation in tractive resistance as do the inter-

mediate and low types, nor does the tractive resistance on pavements reach as high maximum values as those determined for some of the low and intermediate types.

The high tractive resistance of mud is due in part to the necessity of squeezing the mud away from the tire as it rolls through the soft surface layer and in part to a certain springiness of the whole road crust.

The yielding of the foundation under the load, where there is a spongy subgrade under a thin road crust, has been found to add approximately 50 per cent to the tractive resistance at a speed of 20 miles per hour. This condition is perhaps of no great consequence so far as light vehicles are concerned, but is a very important one from the standpoint of the truck and bus operator. On a road in this condition fuel consumption will be markedly greater than on the same road when the foundation is stable and unyielding, as it is when dry.

Rough surfaces of a given type generally have a higher tractive resistance than smooth surfaces of the same type. There is a tendency for the tractive resistance curves on certain varieties of roughness to drop at the higher speeds. In some instances they even cross those for smooth surfaces. In other instances the tractive resistance curves for rough surfaces are at all speeds higher than the corresponding curves for smooth surfaces.

The difference in behavior on different rough surfaces seems to be due to the effect of the resiliency of the tire and spring system. With a certain type of recurring roughness the wheel bounds in such a manner that the tire is partly off the road surface for appreciable time intervals and the distortion of the tire and the power loss therein reduced below that of a smooth surface as the air pressure in the tires is lowered the tractive resistance increases. Laboratory tests indicate that rolling resistance decreases with an increase in the temperature of the tires.

Stream Pollution in Wisconsin (Madison: Wisconsin State Board of Health, Bureau of Sanitation Engineers 1927, pp. XVIII + 328).—The results of the activities of the conservation commission and the State Board of Health of Wisconsin in the control of stream pollution from July 1, 1925, to December 31, 1926, are presented in this report.

Experiments and data collected in regard to the treatment of industrial wastes indicate that the application of 3.25 pounds of ferrous sulfate and 7.25 pounds of lime per thousand gallons of waste, followed by satisfactory sedimentation, will reduce the oxygen demand of pea cannery wastes approximately 75 per cent. The initial cost of installing the necessary equipment for this treatment ranges from $2,000 to $2,800 for a two-line cannery and the cost of operation from $13 to $15 per day. The installation of suitable seveall equipment will economically reduce the waste of paper making material to approximately 0.5 pounds per 1,000 gallons of waste. Aeration and impounding of sulfite liquor from sulfite mills will reduce the oxygen demand 50 to 75 per cent.

Experiments in the chemical treatment of pea cannery wastes preliminary to entering the sewer system at Ripon, demonstrated that the removal of the coagulated solids at the cannery is essential to prevent overloading of the local sewage disposal plant during the canning season. Investigations in the preliminary treatment of knitting mill wastes at Ripon, indicated that lint and greasy constituents, which interfere with the normal operation of the sewage disposal plant, can be removed by fine mechanical screening and ferrous sulfate and lime treatment.

Sewage and industrial waste treatment experiments at Waupun indicated that preliminary sedimentation, chemical treatment and aeration at the sewage disposal plant would yield a satisfactory effluent.

Detailed data from chemical and biolcgical surveys of streams are also presented.

Research in Mechanical Farm Equipment, H. B. Walker (U. S. Department of Agriculture, Miscellaneous Publication 38 (1928), pp. III + 43, figs. 2).—This report presents the results of a survey of research in mechanical farm operating equipment conducted by the Bureau of Public Roads in cooperation with the American Society of Agricultural Engineers and the National Association of Farm Equipment Manufacturers.

A large amount of data is presented on research work in progress in mechanical farm equipment and on the funds and personnel devoted thereto. Special attention is drawn to the organization available for work of this nature, and it is stated that the assistance of the Office of Experiment Stations in the development of comprehensive and coordinated research programs is essential for the maintenance of high standards of investigation in this work. Seven appendixes are included, giving general outlines for projects on the measurement of soil tilth and for a cooperative study in farm machinery for the southern states, the status of projects and problems already being considered by different agencies, and data on the distribution of funds and personnel for agricultural engineering research in the United States for the year July 1, 1926, to June 30, 1927. A brief bibliography is included.

Note on the Effect of Repeated Stresses on the Magnetic Properties of Steel, M. F. Fischer (U. S. Department of Commerce, Bureau of Standards, Journal of Research, Vol. 1 (1928), No. 5, pp. 721-732, pl. figs. 11).—Studies with one per cent carbon steel drill rod and 0.13-per cent carbon, cold-rolled machinery steel showed that the magnetic changes produced by repeated stresses above the endurance limit are not of a type which can be associated with the characteristic effect of a crack transverse to the direction of magnetization. The similarity of the observed magnetic changes with those brought about by the removal of externally applied static stresses indicates that the observed changes may be produced by the partial relief or redistribution of initally existing internal stresses. The fact that the magnetic changes brought about by understressing are of a similar character though less in magnitude suggests that some of the beneficial effect of understressing may be due to partial stress relief.

[Agricultural Engineering Studies at the Illinois Station] (Illinois Station (Urbana) Report 1928, pp. 234-253, figs. 5).—The progress results of experiments on the agricultural use of electricity and the use of big hitches, gas engine lubrication, operation of a general-purpose tractor, corn borer control by machinery, terracing drainage of tight clay soils, combining practice and corn drying are reported.

It was found that where conditions favor the use of large teams, the hitches and methods of driving that have proved practical in grain farming sections of the West and Northwest are also satisfactory under Illinois conditions.

In gas engine lubrication studies there seemed to be a close relation between the ability of an oil to resist crankcase dilution and the number of hours it can be used in an engine.

In drainage experiments it was found that the tile laterals must be spaced reasonably close for quick drainage in the tight clay soils of southern Illinois. Tests of the use of heated air in corn drying showed that a drying temperature of 120 degrees (Fahrenheit) did not lower the germination percentage of the corn, but that a temperature between 140 and 150 degrees materially decreased germination. For practical purposes in the drying of corn for livestock feeding there appears to be no objection to a drying temperature as high as 150 degrees.

The Correct Explanation for the Heaving of Soils, Plants, and Pavements, G. J. Bouyoucos and M. M. McCool (Journal of American Society of Agronomy (Geneva, N. Y.) 20 (1928), No. 5, pp. 480-491, figs. 7).—Studies conducted at the Michigan Experiment Station are reported which indicate that the heaving of soils, plants, and pavements is caused almost entirely by the drawing or accumulation of water on freezing at or near the surface by the force of crystallization. "This frozen water grows upward in the form of massive capillary ice columns, pillars, ridges or solid sheets of ice. As water is pulled or drawn to the points of freezing and as these different forms of ice grow upward, they push upward. This a general fundamental principle and, in one modification or another, underlies nearly all the phenomena of heaving of soils, plants and pavements."

Accelerated Laboratory Corrosion Test Methods for Zinc-Coated Steel, E. C. Groesbeck and W. A. Tucker (U. S. Department of Commerce, Bureau of Standards Journal of Research, 1 (1928), No. 2, pp. 255-295, pls. 14, figs. 6).—A comparative study is reported of the merits of two types of accelerated laboratory methods for evaluating the indicated life of the coating on hot-dip zinc-coated sheet steel.

The two methods studied were the simulated atmospheric corrosion, using a moist gaseous mixture of sulfur dioxide, carbon dioxide and air, and the spray, using normal solutions of sodium chloride and ammonium chloride separately. A consistent relationship between the "life" and weight of the coating was shown by the results. The time required for the breaking down of the coating was considerably less for the first method than for the second. The coating was corroded, in the first method, in a progressive manner over the entire surface and similar to that reported for galvanized materials corroded in the atmosphere under service conditions, and in the second method, in a local and capricious manner. The presence or absence of about 2/10 of 1 per cent copper in the steel base produced no apparent effect on the results. Tests were also made on specimens which had been annealed for the purpose of converting the zinc coating into an iron-zinc alloy.

"The American Society of Heating and Ventilating Engineers Guide" for 1929 is the seventh edition of a highly complete technical and professional guide to heating and ventilating engineering. It contains a text or technical data section, with index; manufacturers catalogue data section, with index; consulting service section; roll of membership of the Society; and a code of ethics for engineers. Of the thirty-four chapters in the technical data section, those on chimneys, fan furnace heating, central heating systems, heat exchangers, laundry, kitchen and hospital equipment, and fans for heating and ventilating, are new. Amplified information on heat losses from buildings, radiators and heaters, steam heating systems and piping, heating boilers, ventilation standards, methods of drying and natural ventilation, is also provided. There are more than 900 pages and many illustrations. The A.S.H.V.E. (New York) publish the book and price it at $5.00.

Who's Who in Agricultural Engineering

D. G. Miller

W. B. Clarkson

E. W. Lehmann

S. P. Lyle

D. G. Miller

Dalton Giles Miller (Mem. A.S.A.E.) is senior drainage engineer with the Division of Agricultural Engineering, U.S.D.A., and is in active charge of a cooperative state and federal drain tile testing and research laboratory at University Farm, St. Paul, Minnesota. He received his bachelor's degree in civil engineering from the University of Iowa in 1905. Soon after he took up drainage work with the U. S. Department of Agriculture and has been at it ever since. The work has taken him to various parts of the country on important assignments. He was one of the pioneers in studying and advocating the drainage of irrigated land. For several years he was stationed in Colorado, and while there incidentally served as consulting engineer for the first organized drainage district to construct a drainage system under the laws of that state. Since 1921 he has been located in Minnesota in his present capacity. His work on the effect of alkalies on the curing and strength of concrete is particularly well known. He is author of a number of bulletins and technical papers on various phases and results of his work. A member of the Society since 1925, he is chairman of its Committee on Ethics.

W. B. Clarkson

William B. Clarkson (Mem. A.S.A.E.) is vice-president and manager of the scientific and experimental department of the King Ventilating Company, ventilating engineers and manufacturers of ventilating systems. He is one of the men who has risen to high executive and scientific position in his field through experience and self-schooling. During his youth he spent four years in the U. S. Navy, starting in as an apprentice boy and receiving his honorable discharge as an able seaman. Leaving the seafaring life he became associated with a farm machinery business and began his development as an agricultural engineer. After thirty years in this business he joined his present associates in the development of the King Ventilating Company. When he became affiliated with the Society in 1916 he immediately showed an active interest in its farm structures work. He suggested and was first chairman of its Committee on Ventilation. As such he induced Dr. H. P. Armsby to write an article the subject of heat given off by cattle, and was influential in getting the U.S.D.A. to put a man on barn ventilation research. He has contributed several technical papers on the subject of ventilation and has also served as a vice-president of the Society.

E. W. Lehmann

Emil Wilhelm Lehmann (Mem. A.S.A.E.), a past-president of the Society, is professor and head of the department of farm mechanics at the University of Illinois. Some steps in his rise to his present position include receiving a bachelor's degree in electrical engineering at Mississippi A. & M. College; three years as instructor in physics at the A. & M. College of Texas; receiving a professional degree in electrical engineering at the A. & M. College of Texas in 1913; a fellowship and bachelor's degree in agricultural engineering at Iowa State College in 1914; positions at the same institution until 1916 as instructor and assistant professor; four years, 1916-1920, as head of the newly organized agricultural engineering department at the University of Missouri; receiving a professional degree in agricultural engineering in 1919 at Iowa State College; and one year as agricultural engineering editor of "Successful Farming." Following the latter position he made his present connection with the University of Illinois in 1921. He has served as chairman and member of many committees of the Society since he became a member in 1916; was its president for the year 1923; and is at present a member of the College Division Advisory Committee.

S. P. Lyle

Samuel Patterson Lyle (Mem. A.S.A.E.) is professor and head of the division of agricultural engineering at Georgia State College. After graduating from high school he farmed for several years and served as pilot in the U. S. Air Service for about two years during the war, before entering college. He received his bachelor's degree in agricultural engineering at Kansas State Agricultural College in 1921; was granted a teaching fellowship at Iowa State College; became affiliated with the Society; in 1922 was granted his master's degree by Iowa State College; and accepted a position as head of the department of agricultural engineering at the State Agricultural School, Jonesboro, Arkansas. After two years there he left to take up his present work. His recent activities in the Society include serving as chairman of the Southern Section in 1928, and at present, as chairman of the Committee on Student Branches, member of the College Division Advisory Committee, member of the Southern Section Committee on Cooperative Machinery Experiments, and one of the representatives of the Society on the Joint Committee on Fertilization Application.

AGRICULTURAL ENGINEERING

Established 1920

A journal devoted to the advancement of the theory and practice of engineering as applied to agriculture and of the allied arts and sciences. Published monthly by the American Society of Agricultural Engineers, under the direction of the Publications Committee.

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Contributions of interest and value, especially on new developments in the field of agricultural engineering, are invited for publication in this journal. Its columns are open for discussions on all phases of agricultural engineering. Communications on subjects of timely interest to agricultural engineers, or comments on the contents of this journal or the activities of the Society, are also welcome.

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RAYMOND OLNEY, Editor

R. C. Palmer, Assistant Editor

The General-Purpose Tractor

THE standard farm tractor, characteristically a power unit for the large farm, has exerted a great influence on agriculture, particularly during the few years just past. The general-purpose tractor, however, is hailed as a power unit for the small farm. What may be its effect on agriculture?

Two principles are involved: (1) In any particular industry a machine influences the marginal size of production unit in the direction of the point in size at which its contribution to production is marginal. The extent of the influence depends upon the relative importance of the machine in the operations of the industry concerned. (2) Profits provide the means and incentive for expansion of the profit-making enterprise and result in increased production and competition in the industry of which the enterprise is a unit.

One hundred acres is about the minimum size of unit on which the use of the standard farm tractor is profitable. Its use has generally resulted in increased profits on farms of one hundred acres or larger; stimulated the profit-making farmers to increase the scale of their operations; resulted in increased farm production; and favored large-scale farming. This is particularly true in the sections devoted principally to small grains, because most of the farms were larger than one hundred acres and because the standard farm tractor met a large share of their power requirements. Obviously it made matters worse for the one and two-horse farmers.

The general-purpose tractor promises to prove profitable on farms as small as fifty acres. Assuming this to be the marginal size unit for general-purpose tractor operation, its influence then will be toward establishing fifty acres as the marginal size of farm unit. It will give the man with between fifty and one hundred acres a fighting chance to compete with larger farms; to make a profit; and to increase the scale of his operations. For the man with less than fifty acres it also must make matters worse, except as it may place his neighbor with more land in the market for his farm.

Two facts suggest that the indicated influence of the general-purpose tractor will be even more widespread and greater in extent than that of the standard farm tractor. As its name indicates, it meets a larger variety of farm power requirements. This extends its field of usefulness to practically all types of farms and to important power operations new to tractors, particularly the cultivation of row crops. Also the number of farms between fifty and one hundred acres in size is much greater than the number of larger farms and the total acreage represented is greater. We may therefore look forward to the general-purpose tractor—the small farm tractor—exerting an even greater influence than the standard farm tractor toward an increase in the size of farm enterprises.

Meeting A Demand

THE commercial and industrial fields have always, to some extent, drawn upon the colleges for agricultural engineers to fill positions in engineering, sales and other departments. The rate at which this has been going on recently, however, has been such as to give rise to considerable comment.

It is an interesting and significant trend. It is an unmistakable indication that the agricultural engineering profession is moving ahead. The peculiar qualifications of our agricultural engineers are being more and more recognized. Moreover, their success in the new fields will create a still greater demand for the product of the colleges. It will also have a tendency to bring about closer cooperation between industry and the educational institutions, a thing to be encouraged.

This development is not making the task of the heads of the agricultural engineering divisions less difficult. Finding properly qualified personnel to replace key men is a big problem, especially when available material is scarce. In many cases it resolves itself into a task of training promising young men to fill positions left vacant.

In addition to this situation the demand for agricultural engineering graduates is rapidly increasing; in fact, it is only beginning. To meet this demand for competent, properly trained agricultural engineers is a problem to which the entire profession might well give most serious attention. It is clearly the job of our profession to meet this need—and it is to our advantage that the product be of the best.

Specialization of Labor

CONSIDERATION of possibilities for increasing efficiency always suggests the question of specialization of labor. In agriculture how and to what extent specialization should be applied is naturally a subject of debate at this time.

The first big step in this direction is specialization of the functions of labor and management. On the majority of farms today the farmer is necessarily both his own manager and a large share of his labor.

It is undeniably true that good management is essential to success in any business enterprise. Management is more highly rewarded than labor, because one man as a manager can contribute more to the success of a business than he can as a laborer, and because managerial ability is scarcer than labor.

Under these conditions it follows that the man with managerial ability can spend his working hours to best advantage in managing. It is also generally true that labor will be used most efficiently and earn the highest remuneration under the best management it can find. As for those who have some managerial ability but who are not capable of general management, they may expect to be most useful and earn the highest rewards as submanagers, superintendents or foremen, in well-managed enterprises.

Specialization along these lines is going hand in hand with engineering progress in contributing to the increased efficiency of agriculture. The necessary economic and social reorganization is taking place as rapidly as capable farm managers can be developed.

A. S. A. E. and Related Activities

TENTATIVE PROGRAM

Twenty-Third Annual Meeting of the American Society of Agricultural Engineers

Baker Hotel, Dallas, Texas, June 24-27, 1929

First Day — Monday, June 24

Forenoon—9:30 to 12:00—College Division Session

E. R. Jones, acting chairman, presiding

1. Report of Committee on the Advancement of Agricultural Engineering Training, Q. C. Ayres, chairman
2. Report of Committee on teaching methods, F. R. Jones, chairman
3. Report of Committee on Farm Mechanics in Secondary Schools, J. G. Dent, chairman
4. "Farm Shop Contests"—M. F. Thurmond, assistant professor of agricultural engineering, A. & M. College of Texas

Afternoon—2:00 to 4:00—College Division Session

E. R. Jones, acting chairman, presiding

1. Report of Committee on Agricultural Engineering Extension, L. A. Jones
2. Report of Committee on Farm Machinery Instruction, H. T. Barr, chairman
3. Report of Committee on Cooperative Relations, F. C. Fenton, chairman
4. "Preparing for Greater Self-Sufficiency on the Farm"—E. R. Jones, professor of agricultural engineering, University of Wisconsin

Evening—8:00

1. Council meeting

Second Day — Tuesday, June 25

Forenoon—9:30 to 12:00—General Session

Wm. Boss, president, presiding

1. Meeting called to order by Dan Scoates, chairman, 1929 Meetings Committee
2. The President's Annual Address—William Boss, chief, agricultural engineering division, University of Minnesota
3. "Soil Erosion and Water Conservation Facts from the Spur (Texas) Experiment"—R. E. Dickson, superintendent, Substation No. 7, Texas Agricultural Experiment Station
4. "Soil Erosion and Water Conservation Facts from the North Carolina Experiment"—F. O. Bartel, associate drainage engineer, U. S. Department of Agriculture. Discussion led by I. D. Wood, extension agricultural engineer, University of Nebraska, and H. H. Bennett, Bureau of Chemistry and Soils, U. S. Department of Agriculture

Afternoon—2:00 to 4:00—General Session

Geo. S. Knapp, first vice-president, presiding

1. "The Federal Soil Erosion Projects"—C. E. Ramser, senior drainage engineer, U. S. Department of Agriculture
2. "The Problem of Silt in Streams and Reservoirs in Texas"—John A. Norris, chairman, State Board of Water Engineers
3. "Roadside and Hillside Protection Against Erosion"—W. H. McPheeters, agricultural engineer, Portland Cement Association
4. "The Banks Interest in Soil Erosion"—A. K. Short, soil conservation agent, Federal Land Bank of Texas
5. "Promoting Terracing work in the Southwest"—M. R. Bentley, extension agricultural engineer, A. & M. College of Texas. Discussion led by G. E. Martin, extension agricultural engineer, Oklahoma A. & M. College

Evening—8:00—Annual Business Meeting

Third Day — Wednesday, June 26

Forenoon—9:30 to 12:00—General Session

Wm. Boss, president, presiding

1. "The Development of the Mechanical Cotton Picker"—(Speaker to be selected)
2. "The Cotton Stripper and Its Problems"—D. L. Jones, superintendent, Substation No. 8, Texas Agricultural Experiment Station
3. "The Cotton Breeder and the Mechanical Harvesting of Cotton"—D. L. Killough, agronomist (cotton breeding), A. & M. College of Texas
4. "The Gins and Present Day Cotton Harvesting"—(Speaker to be selected)

Afternoon—2:00 to 4:00—General Session

1. "Suggestions on the Construction and Operation of Dairy Farm Cooling Plants"—B. D. Moses, assistant professor of agricultural engineering, University of California
2. "The Mechanical Cooling of Homes"—W. E. Brown, Frigidaire Corp.
3. "Some New Ideas in Farm House Design"—D. G. Carter, head, department of agricultural engineering, University of Arkansas
4. "Where Are We Today in Agricultural Engineering?"—Arthur Huntington, public relations engineer, Iowa Railway & Light Corporation

Evening—7:00—Annual A.S.A.E. Dinner

Fourth Day — Thursday, June 27

Forenoon—8:00 to 12:00—Field Demonstrations and Inspection Trips

Afternoon—2:00 to 5:00—Technical Division Sessions

POWER AND MACHINERY DIVISION PROGRAM

R. U. Blasingame, acting chairman, presiding

1. "Research in Power and Machinery, 1928"—R. W. Trullinger, agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture
2. "Results of Recent Cotton Drying Experiments"—C. A. Bennett, associate mechanical engineer, U. S. Department of Agriculture
3. Planning Division Program of Activities—Discussion led by H. E. McCray, C. O. Reed and P. S. Rose
4. Discussion of December Meeting Program of Division—Led by G. W. Iverson, A. P. Yerkes and H. B. Walker

RURAL ELECTRIC DIVISION PROGRAM

E. A. Stewart, chairman, presiding

1. "Model Farms as Operated by Utility Companies"—Richard Boonstra, agricultural engineer, Public Service Corporation of Northern Illinois
2. "The National Project on Rural Electrification"—Geo. W. Kable, director
3. "The Future Place of Electricity in Agriculture"—Arthur Huntington, public relations engineer, Iowa Railway and Light Corporation
4. "Building a Rural Load in the South"—C. T. Gilliam, Central Power & Light Company
5. "Rural Line Construction in Texas"—J. B. Thomas, Texas Power & Light Company
6. "Research in Rural Electrification, 1928"—R. W. Trullinger, agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture
7. "The Portable Motor and Its Use"—W. D. Hemker, agricultural engineer, Wisconsin Power & Light Company
8. "Latest Recommendations on Farm Wiring"—H. S. Hinrichs, rural service engineer, Kansas Power and Light Company
9. "The Field for the Individual Electric Light Plant"—J. R. Golden, Northwestern sales manager, Matthews Engineering Company
10. "Development and Use of the Wind Electric Plant"—George Manikowski, president, Wind Electric Company
11. Report of Committee on Nomenclature and Standard Practice, B. D. Moses, chairman
12. Future Program of Activities of the Division—E. E. Brackett, vice-chairman

LAND RECLAMATION DIVISION PROGRAM

Q. C. Ayres, chairman, presiding

1. "Drainage by Pumping from Wells"—W. W. Weir, in charge, drainage investigations, University of California
2. "Flow of Water in Conduits"—F. C. Scobey, senior irrigation engineer, U. S. Department of Agriculture
3. "Rice Irrigation on the Grand Prairie of Arkansas"—B. S. Clayton, associate drainage engineer, U. S. Department of Agriculture

4. Report of Committee on Run-Off from Agricultural Lands —C. E. Ramser, chairman
5. Report of Committee on Land Clearing—A. J. McAdams, chairman
6. Report of Committee on Drainage in Humid Regions—J. W. Carpenter, Jr., chairman
7. "Research in Land Reclamation, 1928"—R. W. Trullinger, agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture
8. Report of Committee on Soil Hydraulics—F. E. Staebner, chairman
9. Business Session

STRUCTURES DIVISION PROGRAM

J. L. Strahan, chairman, presiding

1. Structures Division Future Program of Activities—J. L. Strahan, chairman
2. Report of Committee on Heating and Ventilating, F. L. Fairbanks, chairman
3. Report of Committee on Fire Protection and Prevention, T. F. Laist, chairman
4. Progress Report of Special Committee on Standards for Dairy Barn Construction—F. C. Fenton, chairman
5. The Federal Project to Coordinate Research in Farm Structures—Henry Giese, assistant agricultural engineer, Iowa Agricultural Experiment Station
6. "Research in Farm Structures, 1928"—R. W. Trullinger, agricultural engineer, Office of Experiment Stations, U. S. Department of Agriculture
7. Discussion of program for December meeting of the Division

Evening—8:00—Technical Division Sessions

(The programs of the technical divisions that are not completed during the afternoon sessions, will be continued in the evening of Thursday, June 27. Other group meetings may be held at this time also.)

New A.S.A.E. Members

L. C. Badgley, president, Badgley Implement Co., Boise, Idaho.

G. R. Brownback, rural salesman, Central Illinois Public Service Co., Canton, Ill.

C. H. Everett, salesman, John Deere Plow Co., Moline, Ill.

H. F. Griswold, factory superintendent, J. I. Case Threshing Machine Co., Racine, Wis.

Ove F. Jensen, assistant director, Northern Division, Soil Improvement Committee, National Fertilizer Association, Washington, D. C.

L. L. Koontz, graduate assistant, Virginia Polytechnic Institute, Blacksburg, Va.

V. L. Oliver, sales engineer, Twin City Separator Co., Fargo, N. D.

T. H. Oppenheim, secretary, New Idea Spreader Company, Coldwater, O.

L. H. Schoenleber, graduate student, Iowa State College, Ames, Ia.

H. E. Stover, rural salesman, Kansas Power and Light Co., Topeka, Kans.

H. K. Taylor, farm sales representative, Jeff Hunt Road Machinery Co., Columbia, S. C.

neering, Clemson Agricultural College, Clemson College, S. C.

Transfer of Grade

R. H. Wileman, assistant in agricultural engineering, Purdue University Agricultural Experimental Station, Lafayette, Ind. (Junior to Associate Member.)

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the April issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

R. C. Beam, development engineer, The American Rolling Mill Co., Middletown, O.

C. C. Bell, manager, rural electrification department, Wisconsin Valley Electric Co., Wausau, Wis.

M. H. Byrom, instructor, A. & M. College of Texas, College Station, Tex.

J. S. Dhillon, student, University of Nebraska, Lincoln, Neb.

K. S. Garcha, student, Loomis, Calif.

J. M. Horner, agricultural engineer, Portland Cement Association, Carlisle, Pa.

E. H. Neal, instructor in irrigation, University of Idaho, Moscow, Ida.

H. C. Rutt, rural salesman, Public Service Company of Northern Illinois, Waukegan, Ill.

P. D. Sanders, manager, The Sanders Farms, Redwood Falls, Minn.

J. L. Schaller, secretary-treasurer, Mendota Mfg. & Transfer Co., Mendota, Ill.

Ersel Walley, general farm manager, The Straus Brothers Co., Fort Wayne, Ind.

Transfer of Grade

Hobart Beresford, professor of agricultural engineering, University of Idaho, Moscow, Ida. (Associate Member to Full Member.)

A. D. Edgar, assistant professor of agricultural engineering, University of Idaho, Moscow, Ida. (Associate Member to Full Member.)

E. G. Lantz, assistant manager, Cement Products Bureau, Portland Cement Association, Chicago, Ill.

Employment Bulletin

An employment service is conducted by the American Society of Agricultural Engineers for the special benefit of its members. Only Society members in good standing are privileged to insert notices in the "Men Available" section of this bulletin, and to apply for positions advertised in the "Positions Open" section. Non-members as well as members, seeking men to fill positions, for which members of the Society would be logical candidates, are privileged to insert notices in the "Positions Open" section and to be referred to persons listed in the "Men Available" section. Notices in both the "Men Available" and "Positions Open" sections will be inserted for one month only and will thereafter be discontinued, unless additional insertions are requested. Copy for notices must be received at the headquarters of the Society not later than the 20th of the month preceding date of issue The form of notice should be such that the initial words indicate the classification. There is no charge for this service.

Men Available

AGRICULTURAL ENGINEER, graduate of Mississippi A. & M. College and North Carolina State College of Agriculture, desires position in college work, either teaching, extension, or research. Has had teaching and extension experience for a period of nine years in southern agricultural institutions and for the past two years has handled work in drainage, irrigation, water supply and plumbing, machinery, building and repair work on a large demonstration farm in the South. MA-157

AGRICULTURAL ENGINEER desiring advancement will consider position as manager of an agricultural enterprise where practical experience coupled with a college training will be appreciated. Has held positions with two of the leading agricultural colleges of the Middle West. Married and 39 years old. Prefer to locate in the Middle West. MA-162.

ELECTRICAL ENGINEER, age 26, desires opportunity to specialize in rural extension work. Has had one year experience in electrical merchandising sales and four years in electrical distribution engineering with large utility company. Lived on farm ten years and understands farm problems. Capable of directing work. Single. Prefers location in Middle West but will consider any place. MA-163.

AGRICULTURAL ENGINEER desires position as teacher in a Southern college. Have had four years' experience teaching agricultural engineering and five years teaching vocational agriculture. While in vocational agriculture work have had outstanding experience in farm shop work and in erecting farm buildings in my community. Age 32. Married. MA-161.

Positions Open

DESIGNING ENGINEER of high character, ability and experience, capable of doing original layout work and acting as assistant in engineering department of company manufacturing tractors, threshers and combines is wanted. PO-153.